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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE INFLUENCE OF THE ENVIRONMENT ON THE MILLING AND BAKING QUALITIES OF WHEAT IN INDIA.

No. 2. THE EXPERIMENTS OF 1909-10 AND 1910-11.

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PREFACE.

THE experiments described in the present paper are a continuation of those dealt with in a previous communication (*Mem. Dept. Agr. in India, Bot. Ser.*, No. 4, Vol. III, 1910).

We desire to take this opportunity of expressing our indebtedness to several officers of the Indian Agricultural Department for their valuable co-operation in the conduct of this work. For facilities at Dumraon and Bankipore we are indebted to Mr. F. Smith, Deputy Director of Agriculture, Bengal. Dr. Parr and Mr. B. C. Burt, the Deputy Directors of Agriculture of the United Provinces, have assisted us at Aligarh and Orai respectively. At Meerut, Babu Jagannath Pershad gave us all facilities on his farm. Khan Bahadur Mohamad Hadi has kindly placed the resources of the Partabgarh Experiment Station at our disposal, while at Lyallpur, Mr. W. Roberts, Professor of Agriculture, has been good enough to assist in the work. For facilities at Hoshangabad in the Narbada Valley we are indebted to Mr. G. Evans. At Raipur, in the Chattisgarh Division of the Central Provinces, Mr. D. Clouston, Deputy Director of Agriculture, has given us very valuable help.

For the very large number of nitrogen determinations involved in the work we are indebted to Dr. J. W. Leather, Imperial Agricultural Chemist.

In the milling and baking aspect of the subject we have been fortunate enough to secure the invaluable assistance of Mr. A. E. Humphries, formerly President of the National Association of British and Irish Millers and a well-known authority on these questions.

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QUETTA,

August 5th, 1912.

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THE INFLUENCE OF THE ENVIRONMENT ON THE MILLING AND BAKING QUALITIES OF WHEAT IN INDIA.

No. 2. THE EXPERIMENTS OF 1909-10 AND 1910-11.

I. INTRODUCTION.

THE question of the influence of environment on the quality of wheat is of the greatest importance to those concerned with the improvement of this crop. It affects not only the question of seed distribution and the introduction of new varieties, but is also of vital interest to the breeder. It has long been a vexed question as to what extent quality in plant products is determined by environment and how far it must be considered as characteristic of the breed. To the plant-breeder, who wishes to combine in one race the largest number of valuable qualities, a knowledge of the respective parts played by breed and by environment in producing such qualities becomes essential. Further, in the general aspect of seed distribution in India it is essential to know in what tracts high milling and baking qualities are possible. For instance, at the present time, the black cotton soils of the Peninsula and the canal irrigated tracts of Northern India produce mainly soft weak wheats often with poor milling qualities. One of the objects of this investigation is to determine whether or not wheats of better quality can be grown in these important areas.

The experimental investigation of this subject in India was commenced in 1907 and the results obtained up to the harvest of 1909 have already been described.[1] Subsequently, the experiments

[1] Howard, Leake & Howard, *Memoirs of the Dept. of Agr. in India* (Botanical Series), Vol. III, No. 4, 1910, p. 191.

have been considerably extended, and in the present paper an account of the work done in the wheat growing seasons of 1909-10 and 1910-11 is to be found.

The characters of the wheat grain which may be affected by change of environment are the following :—

1. *Colour.* While the general colour, red or white, of any wheat remains the same no matter under what conditions it is grown nevertheless the depth or tone of colour in red or white wheats is not constant. In India, white wheats, when well grown under dry farming conditions, are frequently much darker in tint than the same wheat grown carelessly under a superabundant supply of canal irrigation. Similar differences are to be seen in red wheats.

2. *Size and weight of grain.* The size and absolute weight of the grain vary very considerably both in different localities in the same year and also in the same locality in different seasons.

3. *Composition.* Much of the work on the effect of environment on the characters of the wheat grain has been concerned with the effect of change of environment on the nitrogen content of the grain—the nitrogen content being taken not only as a measure of the percentage of gluten, but also as a rough indication of the strength of a wheat. There are, however, exceptions to the general rule that the higher the nitrogen, the greater the strength so that, in the present state of knowledge, the only safe method of estimating strength is by milling and baking tests. Quality as well as quantity of gluten is important in this respect. For a flour to be really strong there must be sufficient gluten of the right quality present. So far, while no accurate relation has hitherto been found between chemical composition and the bread-making value of wheat, nevertheless the trend of recent investigations on this subject affords hope that the strength of wheat may be explained from a chemical standpoint. Thus Wood has found in the case of Fife and other strong wheats that the water soluble phosphates in these flours is high—over 0·1 per cent. and the chlorides and sulphates very low. They also contain more magnesia than lime. Weak wheats on the other hand yield flours

with a low proportion of soluble phosphates, a high percentage of chlorides and sulphates with more lime than magnesia.[1]

4. *Consistency.* The effect of environment on the consistency of the wheat grain, *i.e.*, its translucent or starchy appearance, has been perhaps more thoroughly investigated than any other aspect of the question. There is no doubt that consistency depends very largely on the soil, on the available moisture and on the nutrition of the crop and that, in many cases, great changes take place in this character in any variety according to the conditions under which it is grown. From the miller's point of view the consistency of the sample is of the highest importance and is one of the main factors in determining the value of wheat. Consistency is commercially important in two ways. Firstly, it affects the process of conditioning or the adjustment of water previous to grinding—as a rule translucent wheats take up more water than soft samples. Secondly, translucent grains usually behave better than soft wheats in the mill and are more free grinding, thus enabling the separation of bran from flour to be made with ease. As strong wheats are frequently translucent, translucency is sometimes considered to be an indication of strength, but this is not always the case as both translucent weak wheats and mellow strong wheats occur. In spite of these exceptions, however, the consistency of the grain remains a very important factor in the commercial valuation of a wheat.

5. *Quality.* Good quality in wheaten flour has been defined by Humphries[2] as "the sum of excellence on several points" and these are five in number: (1) flavour; (2) colour of the flour; (3) strength, *i.e.*, size and shape of loaf; (4) stability of dough; (5) yield of bread per sack of flour. It is obvious that information on such points cannot be determined in any other way than by milling and baking tests. In seeking information on the effect of environment on the quality of the grain it is therefore clearly essential to submit the sample to a complete test in the mill and bakehouse.

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[1] See Jago—*The Technology of Breadmaking*, London, 1911, p. 323.

[2] Humphries, *Quality in Wheaten Flour*—a paper read before the Joint Session of the Chemistry, Botany and Agriculture Sections of the British Association at Winnipeg, 1909.

The earlier investigations carried out in Europe and North America, which bear on this subject, have been restricted to a great extent to the influence of external conditions on the composition of wheat. With the exception of the work of Humphries and Biffen[1] in England, little or no attention has been devoted to the more important practical question of the influence of environment on the milling and baking qualities. The earlier literature is referred to in the previous paper and, since this was published, several other contributions to the subject have appeared which are dealt with below.

In the United States, Le Clerc[2] has published a detailed account of his investigations on the influence of environment on the composition of wheat, the work being a continuation of previous experiments on this subject. Wheat from the same original seed was grown continuously at each of the three apices of two triangles (1) Kansas, Texas and California, (2) South Dakota, Kansas and California. The crop from each apex was then sent to the other two stations and then grown under the same conditions as the continuously grown seed. There were thus three plots at each station, all from the same original seed, one plot grown continuously at that point, the seed of the other two plots coming from the other apices of the triangle. Two samples of wheat were used in the experiments (*a*) Kubanka, a spring durum grown at South Dakota, Kansas and California and (*b*) Crimean, a common winter wheat, at Texas, Kansas and California. In the case of both wheats there were great variations in the percentage of nitrogen, in the consistency and in the absolute weight. The crop at each centre, no matter how different the composition and consistency of the seed sown, was practically identical. For example, when Kansas seed with 19·1 per cent. of protein, Texas seed with 12·2 per cent. of protein and the Californian seed with 10·4 per cent. of protein were all grown in California, the composition of the grain from the three plots was almost identical, namely, 11 per cent., 11·4 per cent. and 11·3 per cent. of protein.

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1 Humphries & Biffen, *Journal of Agricultural Science*, Vol. II, 1907, p. 6.

2 Le Clerc, *Bull. 128, Bureau of Chemistry, U. S. Dept. of Agr.*, 1910.

The author concludes that the results indicate that soil and seed play a relatively small part in influencing the composition of crops and that the differences observed are due for the most part to climatic conditions prevailing at the time of growth. The results appear to be open to serious objection and are vitiated by the fact that the samples compared are by no means equally well grown. This is evident on examining the absolute weight of the same wheat grown at the various centres. The weight of 1,000 grains of Kubanka varied from 24·9 to 46·5 grammes while the limits of variation in the case of Crimean were 20·4 and 34·0 grammes. These variations are so great that they are bound to influence considerably the nitrogen content as, other things being equal, the lower the absolute weight the higher the nitrogen. Again, no milling and baking tests were made in these experiments and the conclusions are based entirely on the analytical data.

In Canada, Shutt has continued his investigations on the influence of environment on the composition of wheat, and the results are published in the *Report of the Canadian Experimental Farms* for 1909, 1910 and 1911. The experiments were conducted principally with Fife wheat at Lethbridge in South Alberta and are concerned with the influence of soil moisture on composition. In 1909 and 1910 especially, the samples from the non-irrigated land, in which the soil moisture decreased up to harvest time, contained a much higher percentage of nitrogen than those from the irrigated plots in which the soil moisture was appreciably greater. The samples do not seem to have been milled and baked so that it is not possible to determine how far the milling and baking characters have been influenced by the conditions under which the wheats were produced. Further, the absolute weight in the experiments of 1909 and 1910 is not stated, so that it is not possible to say whether the wheats compared were equally well grown or not.

Evans[1] has conducted some investigations bearing on the influence of soil moisture on consistency and composition in the Central

[1] Evans, *Bull. 3, Central Provinces Department of Agr.*, 1909.

Provinces of India. In durum wheats particularly it was found that the effect of excessive watering was to increase the percentage of soft and spotted grains and to lower the nitrogen content. The number of waterings given was nine and, in consequence, the crops often did not ripen till a month after the normal date. The treatment given was quite exceptional as in India it is not usual to water wheat nine times. Even in the Canal Colonies of the Punjab, where the land was previously a desert, three waterings only is the rule. Speaking generally, irrigation for wheat on the black soil of the Central Provinces is not common as the soil usually contains sufficient moisture for the wheat crop. In these experiments the absolute weight of the sample is not stated so that it is impossible to interpret the figures for the nitrogen content with accuracy.

Leather [1] has published a preliminary note on the effect of manures on the composition of wheat and other grains but no details of the experiments are given.

As in the older work on this subject the recent investigations referred to are all characterised by the absence of milling and baking tests. In order to obtain accurate information on the effect of environment on the behaviour of the same sample in the mill and subsequently in the bakehouse it is, in the present state of knowledge, unsafe to rely on chemical data only and on the appearance of the samples. Such important matters as strength of flour and the freemilling nature of the wheats might easily be masked by changes in consistency and nitrogen content. That this is so is proved by the results described in the present paper.

The agricultural conditions under which wheat is grown in India have been referred to in detail in the previous paper on this subject. India possesses two great wheat tracts which differ from each other both as regards soil and as regards the source of moisture. The more important of these regions is the alluvium of the Indo-Gangetic plain, stretching from Bihar on the East through the United Provinces and the Punjab to Sind on the Western coast.

1 Leather, *Seventh International Congress of Applied Chemistry*, Section VII, 1909, p. 157.

In parts of Bihar, wheat is grown on high moisture retaining heavy loams without irrigation. In Oudh, wells supplement the rainfall, while in the Doab, between the Jumna and the Ganges, and also in the Western Districts of the United Provinces canal water is commonly employed. In the Punjab, the wheat crop is largely watered from perennial and inundation canals while, in Sind, inundation from the Indus takes the place of the monsoon. The predominant features of the wheat tracts of the plains are the alluvial character of the soil and the occurrence of some form of irrigation. The second great wheat growing tract in India is found in the Peninsula on the black cotton soils of the Central Provinces and Bombay. Here irrigation is the exception and most of the wheat is grown on the moisture left in the soil after the previous monsoon.

Besides moisture and soil another factor in Indian wheat production is of importance. This is the length of the growth period. Wheat is generally sown as soon as the temperature falls sufficiently for germination to take place and for the seedlings to develop. The length of the growth period in the spring is also limited by temperature and the rapid advance of the hot season prevents the cultivation of late maturing wheats. The growth period is shortest in Central India and longest in the Punjab and North-West Frontier Province.

The main directions in which Indian wheat can be improved are two—yield and quality. The shortness of the growth period and the fact that the water supply is liable to be deficient in amount indicate that moderate yielding wheats are likely to be the most profitable to the grower over an average of seasons. Higher yielding wheats can be grown with safety only where the supply of moisture is adequate and where the retentive power of the soil is considerable. Compared with the high yielding wheats of Western Europe, where the growth period is long and the rainfall well distributed, the wheats of India are but moderate yielders. Generally speaking, the season is too short in India for the growth of such high cropping wheats as those of France and England. As yield is determined by the length of the growth period and the average water supply, the plant

breeder in increasing the amount of wheat grown, soon reaches the limit imposed by these conditions. In the improvement of the quality of the grain of Indian wheat however there is much greater scope for the breeder. In general, the wheats of the country have poor grain qualities, both from the milling aspect and also from the point of view of breadmaking. Some Indian wheats do not mill well while the majority have a reputation for producing weak flour.

In the improvement of the quality of Indian wheat it is of the first importance to determine how far grain qualities are influenced by environment, and in what tracts high quality wheats retain their characters. Accurate information on the character of the wheat produced in the various tracts and the extent of these tracts will enable a scientific scheme of wheat distribution to be drawn up for the whole of India. It is sometimes stated that high quality wheats cannot be grown either on the black cotton soils or under canal irrigation in the Indo-Gangetic plain, particularly in the United Provinces and the Punjab which produce the bulk of the wheat exported. One of the main objects of these experiments is to test these views and to determine to what extent, if any, canal irrigation interferes with high milling and baking qualities.

The method adopted in this investigation is to compare, as regards consistency, absolute weight, nitrogen content and milling and baking qualities, several pure lines, of widely different quality, grown at various stations. The stations have been selected so as to include as many as possible of the most important wheat tracts of the Indo-Gangetic plain as well as a few places representative of the black cotton soil areas of Peninsular India. When a sufficient number of well-chosen types of wheat, representative of the various classes grown, have been tested in this manner it will be possible to determine how far milling and baking qualities are affected by environment and whether such a change is progressive or whether it takes place once for all.

In the previous paper the results obtained in 1908 and 1909 were described. In both years it was found in the case of Muzaffar-

nagar (a soft, white, weak wheat), grown at different stations in the alluvium, that the samples differed widely in consistency, nitrogen content and to some extent in the milling and baking tests. The results of the two years are summed up in the following tables.

Consistency, composition and baking value of Muzaffarnagar white grown at three stations in 1907-1908.

Where grown.	Colour and Consistency.	% Nitrogen. (Leather).	Order in baking value (Humphries).
1. Pusa	Amber, mostly hard and semi-hard..	1·86	Fifth.
2. Lyallpur ..	Dull white, mostly soft and mottled	1·50	Eighth.
3. Muzaffarnagar ..	White, entirely soft	1·38	Ninth.

Comparative value of Muzaffarnagar white grown at nine stations in 1908-1909.

Where grown.	Consistency.			Weight of 1,000 grains in grammes.	Nitrogen percentage.	Bakers' marks.		Order of merit in commercial value.
	Soft.	Intermediate.	Hard.			Stability.	Strength.	
Cawnpore ..	8	48	39	35·69	2·37	84	75	First.
Pusa ..	16	59	25	38·35	2·00	84	75	Second.
Partabgarh ..	36	33	31	40·02	1·79	82	75	Third.
Dumraon ..	72	21	7	43·67	1·52	78	63	Fourth.
Aligarh ..	76	15	9	42·54	1·30	70	60	Fifth.
Meerut ..	..	..	..	....	1·34	70	60	Sixth.
Bankipore ..	83	13	4	38·95	1·34	68	52	Seventh.
Lyallpur ..	75	20	5	37·08	1·52	68	68	Eighth.
Orai ..	95	0	0	30·97	1·93	64	66	Ninth.

In addition to the tests with Muzaffarnagar white, twenty-five Punjab wheats, belonging to three subspecies, were grown in pure line culture at Cawnpore and compared with the same wheats grown the previous year at Lyallpur. In general, there was a large increase in the proportion of hard grains at Cawnpore and also an increase in the percentage of nitrogen. These wheats have since been grown for two seasons at Cawnpore and at Pusa, and the complete results are described in the next section.

II. THE EFFECT OF ENVIRONMENT ON THE TYPES OF PUNJAB WHEAT.

In 1908, the types of wheat grown in the Punjab were botanically and agriculturally classified at Lyallpur and twenty-five distinct wheats were distinguished. This work has been described in a previous paper.[1] Subsequently, these wheats were grown for three years at Cawnpore and for two years at Pusa. The consistency of the samples, the nitrogen percentage, and the weight of 1,000 grains have been determined and the figures, compared with those obtained from the original seed grown at Lyallpur in 1907-08, are given in the table below.

In considering the results of the determinations of the consistency of the samples it should be remembered that, apart from the influences of the soil and climate, the agricultural conditions under which the samples have been grown at the three stations are not strictly comparable. At Lyallpur, the wheat crop is overwatered and the methods of cultivation are primitive. At Cawnpore, great care is taken to prevent overwatering while at the same time the methods of cultivation have attained a high degree of efficiency. At Pusa, wheat is grown as a dry crop and particular attention has been paid for many years to preliminary cultivation, to the conservation of soil moisture and to the eradication of weeds. The general appearance of the same wheat grown at Cawnpore and Pusa is very similar and the tendency at both stations is to grow similar uniform translucent bright wheats, which take the eye and contain a high percentage of nitrogen. At Lyallpur on the other hand, the production of dull soft samples with a low nitrogen content is the rule. These general results are clearly indicated in the table and

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1 Howard & Howard, *Memoirs of the Department of Agriculture in India* (*Botanical Series*), Vol. II, No. 7, 1909.

in the majority of the types there is a distinct increase in the proportion of translucent grains at Cawnpore and Pusa while at the same time the percentage of nitrogen has increased.

There are three well marked exceptions to the hardening tendency among these wheats. Type 6 has always remained entirely soft at all three stations and no spotted grains have ever been detected. Types 23 & 25 have behaved in a very similar manner and have only rarely produced a few hard and intermediate grains. These examples stand out from the many varieties grown at Pusa in withstanding the hardening tendency which is the general rule at this station. Even in 1911, when the water supply was very short, these wheats, though shrivelled, contained no hard grains. On the other hand, Types 2 & 12 and to a less extent Type 3 have produced a great majority of hard grains at all three stations. Between these two extremes the remaining nineteen types occur producing a considerable proportion of soft grains at Lyallpur and a lesser proportion at Cawnpore and Pusa. Thus there are three classes of wheats among these types, (1) wheats which always remain soft, (2) wheats with a tendency to remain hard and (3) the majority in which the consistency varies greatly according to the locality and the conditions under which they are grown. In the wheats of the last group, as has frequently been observed before, each ear often contains hard, soft, and spotted grains so that the occurrence of all three kinds of grain in the sample is not likely to be due to the result of segregation.

The occurrence of constant soft wheats is of considerable interest and has been noticed in other pure lines at Pusa. One of these, characterised by strong straw, has been used as a parent for improving the standing power of one of the high quality hard wheats. In the second generation of the cross there was a distinct segregation as regards consistency and plants with hard, soft and intermediate grain could be distinguished with ease and certainty. Two other cases of wheats with constant soft grains are of interest from the milling point of view. One of these is that known as "Australian 27" which is largely composed of Punjab Type 25, a type which has

remained soft at Cawnpore and Pusa. The second is a Pusa pure line (No. 3) which has always produced a soft sample. Both these wheats behaved badly in milling and were described as woolly in texture and gave great trouble in the separation of flour and bran. As it is possible that some connection may exist between these bad milling qualities and the tendency to produce a soft sample under all conditions steps are being taken to have complete milling tests made of Punjab Types 6, 23 & 25 when grown at Cawnpore under conditions where most Indian wheats produce samples which mill exceedingly well. At the same time the study of the inheritance of the constant soft character is being continued at Pusa.

The nitrogen content of these constant soft wheats is not without interest. In no case is the percentage really low while in others it is remarkably high as will be seen in the table below. There appears to be no connection between nitrogen content and the tendency to produce soft grains.

Nitrogen content of constant soft wheats.

Name.	Average weight 1,000 grains.	Average nitrogen percentage.
Pusa 3	48·95	2 42
A 88	...	2·21
Punjab Type 6	29·75	1·82
,, ,, 23	32·63	1·80
,, ,, 25	40·97	1·70

In the case of the three Punjab Types the figures are the average of five determinations.

The change in consistency of the 25 types of Punjab wheat when grown at Cawn

Type No.	BOTANICAL VARIETY.	CONSISTENCY.																	NITROG	
		LYALLPUR 1907-08.			CAWNPORE 1908-09.			CAWNPORE 1909-10.			CAWNPORE 1910-11.			PUSA 1909-10.			PUSA 1910-11.			LYALL-PUR.	CA
		Soft.	Intermediate.	Hard.	Soft.	Intermediate.	Hard.	Soft.	Intermediate.	Hard.	Soft.	Intermediate.	Hard.	Soft.	Intermediate.	Hard.	Soft.	Intermediate.	Hard.	1907-08	1908-09.
	T. DURUM Desf.																				
1	Var. *melanopus* Al. ..	9	29	62	0	0	100	0	0	100	0	3	97	0	1	99	0	0	100	1·75	2·60
2	„ *africanum* Kcke. ..	0	9	91	2	5	93	0	1	99	1	5	94	1	9	90	0	0	100	2·61	1·97
3	„ *leucurum* Al. ..	0	4	96	24	25	51	0	1	99	0	0	100	0	2	98	..	..	..	2·20	1·56
	T. COMPACTUM Host.																				
4	„ *erinaceum* Kcke. ..	17	46	37	49	8	43	0	100*	0	0	5	95	0	100*	0	0	3	97	2·14	1·63
5	„ *linaza* Kcke. ..	58	42	0	25	35	40	0	5	95	0	3	97	0	7	93	0	0	100	1·78	1·49
6	„ *Wernerianum* Kcke. ..	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	1·62	1·80
7	„ *Humboldti* Kcke. ..	23	49	28	39	33	28	27	23	50	16	32	52	11	19	70	0	0	100	1·71	1·58
	T. VULGARE Vill.																				
8	„ *barbarossa* Al. ..	21	31	48	0	6	94	2	19	79	1	20	79	0	15	85	0	0	100	1·52	2·16
9	„ *fuliginosum* Al. ..	4	15	81	23	23	54	1	18	81	0	5	95	0	15	85	..	..	..	2·01	1·69
10	„ *erythroleucon* Kcke. ..	51	49	0	0	1	99	0	13	87	4	26	70	0	13	87	0	0	100	1·40	1·75
11	„ „ „ ..	75	25	0	61	29	10	1	9	90	0	5	95	1	14	85	0	0	100	1·34	1·65
12	„ „ „ ..	0	27	73	1	3	96	0	4	96	0	4	96	0	2	98	0	0	100	1·50	2·00
13	„ *ferrugineum* Al. ..	20	36	44	5	7	88	3	39	58	2	25	73	0	0	100	0	0	100	1·57	1·93
14	„ *erythrospermum* Kcke. ..	29	71	0	0	0	100	4	22	74	0	5	75	0	100	0	0	100*	0	1·37	1·90
15	„ „ „ ..	68	32	0	1	8	91	13	33	54	11	25	64	10	26	64	0	0	100*	1·43	2·16
16	„ *græcum* Kcke. ..	88	12	0	34	1	65	10	24	66	30	35	35	12	41	47	0	100*	0	1·39	2·08
17	„ *Delfii* Kcke. ..	25	31	44	7	8	85	0	3	97	2	18	80	0	13	87	0	0	100	1·42	1·71
18	„ „ „ ..	69	31	0	2	3	95	0	15	85	1	13	86	7	46	47	0	100*	0	1·39	2·26
19	„ *leucospermum* Kcke. ..	83	17	0	1	5	94	1	6	93	8	31	61	11	61	28	0	1	99	1·35	2·29
20	„ *alborubrum* Kcke. ..	73	27	0	0	0	100	5	26	69	1	7	92	6	15	79	..	..	..	1·43	2·10
21	„ „ „ ..	62	23	15	0	0	100	0	2	98	0	6	94	5	14	81	0	0	100	1·45	2·54
22	„ *milturum* Al. ..	14	43	43	1	1	98	1	11	88	0	5	95	0	4	96	0	0	100	1·38	2·10
23	„ „ „ ..	100	0	0	98	0	2	100	0	0	98	0	2	98	0	2	100	0	0	1·35	1·95
24	„ *albidum* Al. ..	66	16	18	4	11	85	0	2	98	4	18	78	7	20	73	0	0	100	1·37	1·87
25	„ „ „ ..	92	8	0	99	0	1	95	5	0	96	1	3	100	0	0	100	0	0	1·62	1·52

* Consistency uniform but intermediate between hard and soft.

pore and Pusa.

N PERCENTAGE.				WEIGHT OF 1,000 GRAINS IN GRAMMES.					
WNPORE.		PUSA.		LYALL-PUR.	CAWNPORE.			PUSA.	
09-10.	1910-11.	1909-10.	1910-11.	1907-08.	1908-09.	1909-10.	1910-11.	1909-10.	1910-11.
2·78	2·21	2·24	..	45·80	43·39	37·87	45·20	35·23	33·75
2·31	2·10	2·13	..	50·74	54·65	51·43	48·38	45·35	30·57
2·22	2·16	2·40	..	54·91	52·48	48·45	49·56	42·03	..
1·82	2·06	1·99	..	22·38	27·71	28·81	25·71	29·64	24·44
1·85	2·06	1·86	..	29·54	32·60	30·95	21·07	26·51	18·03
1·81	1·82	2·07	..	31·56	34·48	32·80	25·23	24·46	20·52
1·70	1·86	1·93	..	25·23	31·53	30·90	25·73	22·13	16·53
2·14	2·02	2·03	..	32·16	30·38	34·48	33·76	29·81	20·38
2·14	2·09	1·97	..	32·02	37·06	30·71	22·56	37·33	..
2·09	1·67	1·89	..	33·55	35·61	35·83	35·89	33·68	23·37
2·29	2·13	1·72	..	35·05	29·14	29·39	28·48	30·86	23·15
1·90	1·74	1·88	..	36·40	35·34	37·52	30·94	37·57	28·27
1·89	1·86	2·30	..	35·04	30·37	33·55	27·86	29·61	22·17
1·72	1·85	1·93	..	35·70	35·32	37·80	31·93	36·65	27.05
1·80	1·85	1·83	..	36·44	33·12	39·53	33·63	34·92	24·07
2·06	1·78	1·94	..	33·69	31·38	33·32	31·32	37·88	25·61
1·99	1·72	1·83	..	35·15	38·54	37·06	28·14	44·01	23·86
2·03	1·60	1·64	..	34·53	31·00	33·48	33·22	33·54	22·90
2·24	1·55	1·57	..	31·58	22·20	26·68	24·77	21·43	25·72
·82	1·75	1·57	..	33·59	32·39	31·81	33·50	35·93	..
2·30	1·86	1·66	..	32·40	30·48	34·92	36·13	34·87	28·53
·79	1·92	1·67	..	35·07	38·55	35·89	35·09	35·92	28·10
2·20	1·79	1·71	..	33·13	33·83	32·76	32·44	31·02	27·48
2·42	1.80	1·73	..	36·48	38·04	34·21	36·84	33·38	27·90
·99	1·59	1·71	..	38·26	41·99	38·38	40·45	45·76	37·81

III. THE INFLUENCE OF ENVIRONMENT ON GRAIN QUALITY.

A. The results obtained in 1909-10.

In this section the results obtained by growing the same wheat at different stations and comparing the produce are dealt with. During the season 1909-10, two wheats were grown at the ten stations referred to below and complete milling and baking tests were made in all cases. The two wheats selected were Muzaffarnagar white, (*T. vulgare* Vill. var. *graecum* Kcke.) a weak, soft, white wheat from the Muzaffarnagar District in the United Provinces and Pusa 20, a pure line selected from a Bengal durum wheat, (*T. durum* Desf. var. *apulicum* Kcke.) The experiments with Muzaffarnagar white are in continuation of those described in the previous paper, and the seed sown at each station was taken from the crop of the previous year grown at that station. In the case of Pusa 20 the seed was taken from the bulk grown at Pusa. The ten stations at which these wheats were grown were :—

1. *Pusa.* This station is situated in North Bihar, a tract in which wheat is grown without irrigation on high moisture retaining loams containing about 30% of calcium carbonate.

2. *Cawnpore.* At this station, which is typical of the important wheat tract known as the Middle Doab, wheat is grown on strong loams with canal irrigation.

3. *Partabgarh.* This station represents the wheat growing tracts of Oudh where the crop is grown on well irrigation.

4. *Meerut.* This station, where the samples were grown by a local *zemindar* in the country fashion, is typical of the large wheat growing tract of the Upper Doab and is practically identical with the neighbouring Muzaffarnagar District.

5. *Aligarh.* The conditions at this station are similar to those obtaining in the Meerut District. This centre is therefore a duplicate of the above and both are situated in canal irrigated tracts.

6. *Hoshangabad.* This centre, which is situated outside the Indo-Gangetic alluvium, is characteristic of the black cotton soil of Peninsular India on which wheat is grown year after year on the moisture stored up in the soil from the previous monsoon. Both Muzaffarnagar white and Pusa 20 did not grow to perfection on the soil moisture available and proved to be late varieties for this tract.

7. *Orai.* This station, which is also outside the Gangetic alluvium, is situated in Bundelkhand where wheat is grown on moisture retaining clays which are however sometimes watered.

8. *Bankipore.* This station is situated in Bihar on the south bank of the Ganges, but the soil is not alluvial in character. It is a heavy moisture retaining clay not unlike some of the soils of Peninsular India.

9. *Dumraon.* This station occurs in the wheat growing tracts in South Bihar. The soil is sandy and possesses little or no moisture retaining capacity. In consequence even with irrigation the yields of grain and straw are small.

10. *Lyallpur.* This station is typical of the canal irrigated tract known as the Chenab Colony which produces a large proportion of the wheats exported from Karachi. Overwatering is common while the general standard of cultivation for the wheat crop is below that practised by the best cultivators in the Eastern Punjab and in the Upper Doab.

The soil and moisture conditions at these ten stations vary greatly. On the one hand at Pusa and Hoshangabad wheat is grown almost entirely as a dry crop, while at the rest of the stations the soil moisture is supplemented by varying amounts of canal or well water. In addition, the standard of cultivation at all the stations is not the same as will be seen on comparing the details of preparation for the crop at the various centres. On the alluvial soils of

Trial of Muzaffarnagar White at ten sta

	Pusa.	Cawnpore.	Partabgarh.	Meerut.	Aligarh.	Hos
1. Type of soil ..	Second class loam.	Loam (*dumat*).	Loam (*dorasa*).	Loam.	Light loam.	Black
2. Previous crop ..	Gram in *rabi* of 1908-09 ploughed in.	Mixed crop of *arhar* and *juar*.	Sugarcane.	Sugarcane.	Cotton.	Whea
3. Manuring ..	Green manured with gram in the previous *rabi*.	Nil.	Nil.	Nil.	Poudrette containing 50 lbs. nitrogen per acre.	
4. Preparation for wheat	Exposed several times by iron ploughs during previous hot season, afterwards fallowed.	Ploughed six times before sowing with iron ploughs on 1st April, 15th June, 5th Aug., 14th, 20th & 29th Sep. 1909.	Ploughed four times with iron ploughs on 2nd, 18th Aug., 12th Sep. and 2nd Oct. 1909, and three times with the country plough on 15th Aug., 8th and 15th Oct. 1909.	Ten ploughings with country plough after beginning of the rainy season.	Three ploughings with iron ploughs (28th Jan., 14th July, 9th Aug. 1909), and five times with the country plough (17th and 28th Aug., 13th and 18th Sep. and 8th Oct. 1909).	Plou with plou scar time *bak*
5. Date and method of sowing	18th Oct. 1909, behind the country plough.	24th Oct. 1909, behind the country plough.	17th Oct. 1909, behind the country plough.	9th Nov. 1909, behind the country plough.	31st Oct. 1909, behind the country plough.	18th with try
6. Seed rate (lbs. per acre)	55	120	108	60	100	9
7. Rainfall in inches — April 1st to sowing time.	75·37	30·8	50·21	33·52	21·34	3
7. Rainfall in inches — During growth period	0·22	1·81	1·40	2·59	2·28	
8. Irrigation ..	Once, December 1909.	Twice from canal on 28th Nov. 1909 & 28th Jan. 1910.	Twice from well on 17th Nov. & 10th Dec. 1909.	Twice.	Three times (17th Nov. 1909, 2nd Feb. & 6th March 1910).	
9. Date of harvesting	29th March 1910.	6th April 1910.	29th March 1910.	14th April 1910.	16th April 1910.	16th
10. Growth period in days	162	164	163	156	167	14
11. Consistency of sample — % Soft	0	5	50	54	57	6
11. Consistency of sample — % Intermediate	57	72	38	30	35	
11. Consistency of sample — % Hard	43	23	12	16	8	2
12. Nitrogen percentage	2·19	1·79	1·49	1·79	1·60	
13. Weight of 1,000 grains in grammes	39·80	38·07	39·71	37·92	34·58	3
14. Order of merit in commercial value	First.	Second.	Third.	Fourth.	Fifth.	

tions, 1909-10.

ANGABAD.	ORAI.	BANKIPORE.	DUMRAON.	LYALLPUR.
cotton soil.	Typical wheat soil (*mar*).	Heavy clay.	Sandy loam.	Sandy loam.
t.	Gram.	*Juar* (crop failed).	*Aus* paddy.	Wheat.
Nil.	Nil.	Nil.	Cowdung at the rate of 83 mds. per acre on 17th October 1909.	Nil.
hed once country gh and ified four s with the ar.	Ploughed once with country plough (17th May 1909), twice with iron plough (21st Aug., 13th Sep. 1909) and scarified once with *bakhar* (30th Sep. 1909).	Ploughed eight times between 27th and 29th Oct. 1909.	Ploughed seven times before sowing between 12th Sep. and 26th Oct. 1909.	Ploughed four times with the native plough. One irrigation during preliminary preparation.
Oct. 1909, the coun- drill.	15th Oct. 1909, behind the country plough.	29th Oct. 1909, with local drill.	27th Oct. 1909, with the local drill.	6th Nov. 1909, after the country plough.
05	108	100	100	48
2·4	44·74	46·98	46·25	20·41
1·67	0·58	0·00	1·64	2·09
Nil.	Twice (7th Dec. 1909 & 9th Feb. 1910).	Once (21st Nov. 1909).	Three times (3rd Dec. 1909, 8th Feb. & 8th March 1910).	Four times—once by accident in April, ten days before harvest.
larch 1910.	1st April 1910.	30th March. 1910.	4th April 1910.	21st April 1910.
9	168	145	159	166
6	66	79	58	78
7	29	14	36	16
7	5	7	6	6
2·05	1·45	1·48	1·41	1·38
3·30	37·65	42·58	40·73	40·47
Sixth.	Seventh.	Eighth.	Ninth.	Tenth.

the plains of India wheat comes to perfection only if the soil has been well prepared beforehand and when this preparation extends over a sufficiently long period. To obtain optimum results, both as regards yield and quality, this preparation should extend over the previous hot season as well as during the rains. It is only when the soil has been exposed to the sweetening influences of the sun and air during the hottest part of the year in April and May (which process also kills out most weeds) and subsequently cultivated during the monsoon that the maximum amount of moisture can be absorbed and the soil brought into the highest condition of fertility for wheat. A hurried preparation always adversely affects the yield and is also reflected in the poor general appearance, low nitrogen content and in the milling and baking results. On the other hand, where great attention is paid to cultivation, clean weeding and moisture conservation, the samples are bright and well grown and take the eye. They also tend to contain a high percentage of nitrogen and invariably do well in the milling and baking tests.

Muzaffarnagar White.

For the season 1909-10 the details relating to the trial of this wheat at the above ten stations are to be found in the table opposite and the result of the milling and baking tests are referred to in the following extract from Mr. A. E. Humphries' report, dated October 27th, 1910.

Muzaffarnagar.

"I understand all ten lots were produced from the same seed but that each one was grown at different places, Pusa, Bankipore, Dumraon, Partabgarh, Cawnpore, Orai, Aligarh, Meerut, Lyallpur and Hoshangabad. In 1909, I tested sample lots of this wheat grown at the nine places mentioned first in the list. I note that the Hoshangabad sample represents a lot grown experimentally in a new environment. There were great differences between the 1909 lots which would represent "several shillings per quarter." The lot in that season from Orai was a "dingy looking shrivelled wheat,"

the Lyallpur lot had a poor appearance but yielded better flour and bread than its appearance would lead one to expect. This year the ten lots do not show such great differences in appearance and all of them may be described as good looking specimens of the variety. The Hoshangabad lot contains a considerable percentage of light grains and some greenish or actually green ones. It will be interesting to know whether these blemishes were caused by early cutting or by the wheat maturing too late for the locality. Be that as it may, it is nevertheless a good lot of wheat. The Bankipore lot also contains a few greenish corns and the same ideas suggest themselves but in lesser degree. The Hoshangabad, Aligarh and Dumraon lots are smaller in the berry than the other lots, but a miller who wanted soft, weak wheat, suitable for making biscuit or pudding flours, or who wanted some soft weak flour for toning down the harshness of other kinds, would be very hard to please if he were not content with any one of these lots. The Pusa lot is particularly well grown. In buying wheats, especially those which are not in large regular supply a miller has to base his ideas as to commercial value on many points by appearance and before I had milled and baked any of these lots I had placed them in the following order, and assessed the difference in money value between the best and worst at 1/-per quarter only. It may be interesting to place last year's order in juxtaposition.

1909.	1910.
Cawnpore	Pusa.
Pusa	Cawnpore.
Partabgarh	Partabgarh.
Dumraon	Meerut.
Aligarh	Aligarh.
Meerut	Hoshangabad.
Bankipore	Orai.
Lyallpur	Dumraon.
Orai	Lyallpur.

In view of remarks which I make at the end of the report concerning the influence of water supply on quality it may be worth

mentioning that the moisture content of the Lyallpur lot was very low on its arrival here, but I attach little importance to that under the circumstances, for the others may perhaps have taken up water from the atmosphere in transit. The lots from Pusa, Dumraon and Lyallpur are harder than the remainder; but none of them are hard, all are in the category of soft wheats, and in milling them the moisture content would have to be kept relatively low if satisfactory separations are to be made easily. The Orai, Aligarh and Meerut lots are distinctly "woolly" in texture, whereas the Dumraon lot, in spite of its pale "starchy" appearance, behaves notably well for the variety in milling. The outstanding features of the bakehouse results are three.

1*st*. The superiority of the Pusa lot, which tallies with its appearance as specified hereinbefore.

2*nd*. The way in which the Pusa and Hoshangabad responded when a form of malt extract was added.

3*rd*. The dull uniformity of the remainder in yielding poor miserable loaves under all conditions.

No one used to eating average London bread would buy such poor stuff as the eight poorest yielded. The exterior appearance was wretched, in the Lyallpur case particularly so, for in addition to the chalky-hued, hard, thick crust, characteristic of the variety, that lot exhibited the peculiar cracking of the crust characteristic of English Rivet wheat. The loaves from the eight did not expand in the oven, so they were of very small volume. The flavour of the bread was poor or definitely bad. The case of the Hoshangabad lot was remarkable. At the first baking when the dough was made with flour, yeast, salt and water only, it was certainly better than the eight lots already referred to, but it was not good. When, however, a form of malt extract was added in the second baking a transformation was effected. The loaf was larger, and of pleasing appearance, its flavour was very greatly improved. It is obvious that this lot possessed potentialities which would be readily developed by skilful treatment at the hands of the miller or baker, whereas so far as I have been able to go, on the quantities of wheat

available this season, the eight lots do not seem to possess those potentialities. The Pusa lot was much superior to the remainder throughout the baking trials. It responded to the addition of malt extract but not to so great an extent as the Hoshangabad lot. This means, that at the first baking the former was much superior to the latter and that at the second baking the former was still superior to the latter, but not in the same degree.

I have already in this as well as in former reports said that this variety of flour is quite suitable for pudding or cake making ; indeed, for such purposes it would probably be superior to other varieties much more suitable for bread making. For pudding and similar purposes, it would be judged by its appearance as flour, and its poor or bad flavour would be disguised by the fats, mineral salts and spices mixed with it. For bread making purposes the Pusa stands out as being very much the best lot, but the flour itself produced from it is not so white as that produced from seven of the other lots. Of Hoshangabad the same remark can be made. That flour has a yellow hue. The Lyallpur lot has a dingy hue. The last named lot I would therefore now unhesitatingly place last in the list. It is poor both as flour and as bread, and that in my opinion overrides the superiority it shows in the milling processes.''

In a subsequent communication, dated December 8th, 1909, Mr. Humphries has forwarded the bakers' marks of the ten samples of Muzaffarnagar. The results are as follows :—

	Without malt extract.		*With malt extract.*	
	Stability.	Strength.	Stability.	Strength.
Pusa	80	72	88	79
Hoshangabad	74	62	82	81
Cawnpore	72	62	72	64
Meerut	70	62	70	64
Aligarh	70	62	70	62
Dumraon	72	62	75	60
Partabgarh	70	62	66	60
Orai	72	62	70	60
Bankipore	72	62	70	60
Lyallpur	70	62	68	60

	Pusa.	Hoshangabad.	Aligarh.
1. Type of soil	Second class loam.	Black cotton soil.	Light loam.
2. Previous crop	Gram in *rabi* of 1908-09 ploughed in.	Wheat.	Cotton.
3. Manuring	Green manured with gram in the previous *rabi*.	Nil.	Poudrette containing 50 lbs. nitrogen per acre.
4. Preparation for wheat	Exposed several times by iron ploughs during previous hot season, afterwards fallowed.	Ploughed once with country plough, scarified four times with the *bakhar*.	Three ploughings with iron plough (28th Jan., 14th July, 9th Aug. 1909), and five times with country plough (17th and 28th Aug., 13th and 18th Sept., and 8th Oct. 1909).
5. Date and method of sowing	18th Oct. 1909, behind the country plough.	18th Oct. 1909, with the country drill.	31st Oct. 1909, behind the country plough.
6. Seed rate (lbs. per acre)	55	95	100
7. Rainfall in inches — April 1st to sowing time	75·37	32·40	21·34
7. Rainfall in inches — During growth period	0·22	1·67	2·28
8. Irrigation	Nil.	Nil.	Four times (17th Nov. 1909, 2nd Feb., 6th & 28th March 1910).
9. Date of harvesting	28th March 1910.	16th March 1910.	16th April 1910.
10. Growth period in days	161	149	167
11. Consistency of sample — % Soft	0	0	0
11. Consistency of sample — % Intermediate	0	10	4
11. Consistency of sample — % Hard	100	90	96
12. Nitrogen percentage	2·64	2·47	2·01
13. Weight of 1,000 grains in grammes	42·37	33·87	31·86
14. Order of merit in commercial value	First.	Second.	Third.

of Pusa 20 at ten stations, 1909-10.

CAWNPORE.	DUMRAON.	MEERUT.	ORAI.	BANKIPORE.	PARTABGARH.	LYALLPUR.
Loam (*dumat*).	Sandy loam.	Loam.	Typical wheat soil (*mar*).	Heavy clay.	Loam (*dorasa*).	Sandy loam.
Mixed crop of *arhar* and *juar*.	*Aus* paddy.	Sugarcane.	Gram.	*Juar* (crop failed).	Sugarcane.	Wheat.
Nil.	83 mds. cowdung per acre on 17th October 1909.	Nil.	Nil.	Nil.	Nil.	Nil.
Six ploughings with iron plough on 1st April, 15th June, 5th Aug., 14th, 20th and 29th Sep. 1909.	Ploughed seven times before sowing between 12th Sep. & 26th October 1909.	Ten ploughings with country plough after the beginning of the rainy season.	Ploughed once with country plough (17th May 1909), twice with iron plough (21st Aug., & 13th Sep. 1909), and scarified once with the *bakhar* (30th Sep. 1909).	Ploughed eight times between 27th and 29th Oct. 1909.	Ploughed four times with iron plough (2nd and 18th Aug., 12th Sep. & 2nd Oct. 1909), three times with the country plough (15th Aug., 8th and 15th Oct. 1909).	Ploughed four times with the native plough. One irrigation during preliminary preparation.
24th Oct. 1909, behind the country plough.	27th Oct. 1909, with the local drill.	9th Nov. 1909, behind the country plough.	15th Oct. 1909, behind the country plough.	29th Oct. 1909, with the local drill.	17th Oct. 1909, behind the country plough.	6th Nov. 1909, behind the country plough.
120	100	60	108	100	108	48
30·82	46·25	33·52	44·74	46·98	50·21	20·41
1·81	1·64	2·59	0·58	0·00	1·40	2·09
Twice from canal (28th Nov. 1909, 28th Jan. 1910).	Three times (3rd Dec. 1909, 8th Feb., & 8th March 1910).	Three times.	Twice (7th Dec. 1909 & 9th Feb. 1910).	Once (21st Nov. 1909).	Twice from well (17th Nov. 1909 & 10th Dec. 1909).	Four times. Once by accident 10 days before harvest.
3rd April 1910.	4th April 1910.	14th April 1910.	1st April 1910.	30th March 1910.	29th March 1910.	21st April 1910.
161	159	156	168	145	163	166
0	0	6	0	0·	0	11
1	16	25	13	13	18	55
99	84	69	87	87	82	34
2·26	1·70	2·06	1·90	1·81	1·69	1·72
32·66	41·12	30·04	35·56	41·91	38·06	36·35
Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.

Pusa 20.

The details relating to the trial of this wheat at the ten stations are given in the table opposite and the results of the milling and baking tests are described in the following extract from Mr. A. E. Humphries' report of 1910.

"If it be desirable in the interests of the producer to grow Durum wheats in India, I think it would be desirable to encourage the distribution of this variety of that type. The latest developments in the art of milling minimize to some extent the objections of millers to Durums, but those objections persist and are likely to do so. But there are Durums and Durums, and this variety is a good one. At its best it differs very little in appearance from some of the best hard 'ordinary' wheats, and in milling it, I have found with very much interest that we have obtained, without any special effort, on an average of the ten samples in each case a rather higher percentage of flour than we obtained from the Muzaffarnagars. This to a miller is very noteworthy.

The ten samples were grown at the same places as the ten samples of Muzaffarnagar. In the former set there are the same sort of differences as in the latter. Here also the Hoshangabad lot contains a proportion of thin grains and some which are green. The Cawnpore also contains a few thin grains, but on this point the Meerut lot contains a much larger proportion and a substantial proportion of pale corns besides. The Lyallpur contains a still larger proportion of pale corns and is the poorest of these lots in general appearance. In these ten samples also we get differences in hue, some of a much deeper yellow than others. In the Pusa Muzaffarnagar the deeper yellow hue improves its appearance, but in the Pusa Durum the intensity of its yellow hue detracts from its looks. The Pusa Durum is also very regular in its texture and is particularly well grown.

In spite of these blemishes all the lots with the exception of Meerut may be described as well grown. The Pusa lot appeared on first examination to be hardest, but after conditioning the Cawnpore was found to be so. Judged by appearance only, I should

consider the best worth one and sixpence per quarter more than the worst, and I should place them in the following order:—

Dumraon, Orai, Bankipore
Cawnpore
Partabgarh
Aligarh
Pusa
Hoshangabad
Meerut
Lyallpur.

The subsequent baking trials in these cases caused me to change my opinions, but I am putting my first impressions on record for they would be the basis upon which I should make, at least the earliest, purchases of such wheat. Their behaviour in milling calls for no special comment beyond the one already made. Such flours as these are not at all likely to be sold by appearance, but it may as well be recorded that they are, even after conditioning of the wheat, very granular, that the Meerut and Aligarh lots have a very yellow hue, that the Dumraon and Orai lots are the best judged by appearance and Pusa the worst. When baked into bread Pusa again shows a great superiority with Hoshangabad a good second. From the Durums of commerce, one does not usually obtain tough doughs nor do eight of these lots behave in that way, but the Pusa lot does so and so far as toughness of dough is concerned the Hoshangabad lot is as good. The Pusa yields however decidedly the best loaf, the Hoshangabad is not far behind, the Lyallpur loaf is decidedly the worst with low volume and a poor crust; the Meerut is almost as bad. The other six lots are, within the margin of experimental error, alike. The flavour of the bread produced from each one of them is very pleasant. In these ten cases I made no attempt to add yeast foods or similar materials. It seemed to me desirable to get this set of baking trials made in the simplest way."

In a subsequent communication, dated December 8th, 1910, Mr. Humphries forwarded the bakers' marks of the above wheats. The results were as follows :—

	Stability.	*Strength.*	
Pusa	.. 88	80	Makes tough doughs of a style of toughness which we expect to get in American spring wheat.
Hoshangabad	.. 80	74	In lesser degree has the same toughness in dough as the Pusa lot.
Aligarh	.. 75	65	Cannot be described as tough in dough.
Cawnpore	.. 75	65	Ditto.
Meerut	.. 70	64	Lacks toughness in dough.
Dumraon	.. 70	64	
Orai	.. 65	62	Yields a poor crust similar in character to our English Rivet wheat.
Bankipore	.. 70	62	
Partabgarh	.. 65	60	Dough has very little tenacity.
Lyallpur	.. 70	57	Yields a very fairly tough dough, but a miserable loaf, with a cracked "rivety" crust of very poor appearance.

In the following season, 1910-11, samples of this wheat from the ten stations were grown side by side at Pusa and then compared in all respects. No differences could be distinguished in the plots themselves which behaved exactly alike in the field and the crop to the eye was absolutely level. As regards the grain the samples were alike in appearance and consistency and, as was expected, none of the differences noted in the original samples sown manifested themselves at harvest time. In this case the environmental differences disappeared as soon as the wheat was brought back to its original home, thus confirming Le Clerc's observations on this point in the United States.

B. The influence of environment on strength.

It will be seen in the extensive trials of the weak wheat from the Muzaffarnagar District that in no case did this variety become strong. All that occurred was that at stations like Cawnpore and Pusa, where particular attention has been paid to growing the wheat crop to perfection, the sample improved both in appearance and also in the milling and baking processes. The wheat, however, still behaved as a weak wheat and exhibited all the characteristics of its class.

The behaviour of wheats, characterised by strength of flour and good milling qualities, when grown under similar conditions to Muzaffarnagar, must now be considered. For the purpose of ascertaining how far strength and other desirable grain qualities are maintained, four types of strong wheat (Pusa 4, 8, 12 & 22) were selected. In addition, a sample of Muzaffarnagar was also grown at each centre, so that the strong types could be compared with a typical Indian wheat. The strong wheats selected were not of the same class. Pusa 4 is a large grained, amber wheat with strong straw, which comes to maturity with great rapidity. It is likely to prove of use in those tracts of India where the crop has to be grown on the minimum amount of water. It is also being tried in Bihar as a cover crop for Java indigo, the two crops being sown together as in the case of clover and barley in Europe. Pusa 8 is also an early white wheat with good straw, but the sample is mellow rather than translucent. Pusa 12 is a high yielding, white wheat with a large almost translucent grain, but this line ripens much later than the above and also tillers more. Pusa 22 is a distinctly hard translucent amber coloured wheat of Fife shape, but the straw is not strong enough to support a really heavy crop. Thus of the four strong wheats two, Nos. 4 and 22, are translucent with a dark amber tint, while No. 8 is distinctly mellow. No. 12 is intermediate between No. 8 and the two translucent lines.

The stations at which these wheats were grown were the same as in 1910 except that Raipur was substituted for Hoshangabad.

Trial of Muzaffarnagar white at nine station

	Cawnpore.	Pusa.	Aligarh.	Bankipore.	Lyallpur.
1. Type of soil ..	Heavy loam.	Light loam.	Loam.	Stiff clay.	Sandy loam.
2. Previous crop ..	Cotton.	Wheat.	Cotton.	*Aus* paddy reaped on 29th Sep. 1910.	*San* ploughed in
3. Manuring ..	Nil.	Nil.	63 mds. poudrette per acre.	Nil.	*San* ploughed in 1st Oct. 1910.
4. Preparation for wheat ..	Ploughed six times with iron ploughs (14th March, 9th July, 3rd & 31st Aug., 19th Sep. & 13th Oct. 1910). Once with country plough (18th Oct. 1910).	Exposed several times by iron ploughs during previous hot season, afterwards fallowed.	Ploughed three times with iron ploughs (15th Jan., 6th Aug. & 21st Sep. 1910), and five times with the country plough (28th July, 30th Sep., 11th, 24th, 27th and 30th Oct. 1910).	Ploughed eight times between 4th & 6th Nov. 1910.	Harrowed on 2 Oct. 1910 irrigated on Nov. 1910, vious to sow Ploughed on Nov. 1910.
5. Date and method of sowing	28th Oct. 1910, behind the country plough.	22nd Oct. 1910, behind the country plough.	5th Nov. 1910, drilled.	8th Nov. 1910, with local drill.	12th Nov. 1 behind the c try plough.
6. Seed rate (lbs. per acre)	60	55	82	100	60
7. Rainfall in inches — April 1st to sowing time	26·54	32·11	26·30	55·59	15·52
7. Rainfall in inches — During growth period	1·87	1·42	2·57	1·03	4·05
8. Irrigation	Once (12th Nov. 1910).	Nil.	Three times (5th Dec. 1910, 9th & 27th Feb. 1911).	Once on 19th Jan. 1911.	Four times (Dec. 1910, Feb., 8th Mar 13th April 19
9. Date of harvesting	29th March 1911.	27th March 1911.	12th April 1911.	4th April 1911.	22nd April 191
10. Growth period in days	151	156	158	147	161
11. Consistency of sample — % Soft	3	0	42	60	85
11. Consistency of sample — % Intermediate	58	72	45	35	15
11. Consistency of sample — % Hard	39	27	13	5	0
12. Nitrogen percentage	1·93	2·05	1·34	1·46	1·43
13. Weight of 1,000 grains in grammes	34·18	33·03	28·84	35·51	36·15
14. Order of merit in commercial value	First.	Second.	Third.	Fourth.	Fifth.

ɜ, 1910-11.

	Meerut.	Orai.	Partabgarh.	Dumraon.
	Heavy loam.	Typical wheat soil (*mar*).	Loam.	Sandy loam.
ı.	Peas.	Gram.	Wheat.	Wheat.
ı on	Nil.	Nil.	Nil.	83 mds. of cow-dung applied on 20th Oct. 1910.
9th and 5th ore-ing. 0th	Seven ploughings with the country plough (20th July, 4th & 16th Aug., 25th Sep., 18th, 23rd & 25th Oct. 1910).	Ploughed once with iron plough on 21st July 1910, and cultivated once with the *bakhar* on 16th Oct. 1910.	Ploughed five times with iron ploughs (7th & 11th April, 5th May & 6th June, 7th July 1910), and five times with the country plough (16th July, 13th, 18th, 22nd & 23rd Oct. 1910).	Ploughed eight times between 7th June 1910 and 21st Oct. 1910.
910, oun-	2nd Nov. 1910, behind the country plough.	6th Nov. 1910, behind the country drill.	24th Oct. 1910, behind the country plough.	30th Oct. 1910, with local drill.
	100	100	120	100
	29·23	36·50	45·21	48·96
	5·52	2·58	4·33	3·42
2nd 6th h & 11).	Once on 3rd Dec. 1910.	Once on 21st Dec. 1910.	Twice (8th Dec. 1910 & 11th Feb. 1911).	Twice (12th Dec. 1910 & 12th Feb. 1911).
.	14th April 1911.	5th April 1911.	22nd March 1911.	1st April 1911.
	163	151	148	153
	15 65	44 49	27 61	63 29
	20	7	12	8
	1·75	1·44	1·43	1·65
	30·52	31·18	34·18	29·05
	Not tested.	Not tested.	Not tested.	Not tested.

Trial of Pusa 8 at nine stations, 191

	Cawnpore.	Pusa.	Aligarh.	Bankipore.	Lyallpur.
1. Type of soil	Heavy loam.	Light loam.	Loam.	Stiff clay.	Sandy loam.
2. Previous crop	Cotton.	Wheat.	Cotton.	*Aus* paddy harvested on 29th Sep. 1910.	*San* ploughed in.
3. Manuring	Nil.	Nil.	63 mds. poudrette per acre.	Nil.	*San* ploughed in 1st Oct. 1910.
4. Preparation for wheat	Six ploughings with iron ploughs (16th March, 9th July, 3rd & 31st Aug. 1910, 19th Sep. & 13th Oct. 1910). Once with the country plough (18th Oct. 1910).	Exposed several times by iron ploughs during previous hot season, afterwards fallowed.	Five ploughings with iron ploughs (10th Jan., 5th & 27th Aug., 5th & 22nd Sept. 1910). Six ploughings with country ploughs (27th July, 28th Sept., 12th, 24th, 27th & 30th Oct. 1910).	Ploughed eight times with iron ploughs between 4th and 6th Nov. 1910.	Harrowed on 2 Oct. 1910 and gated on 5th 1910, previous sowing. Plou ed on 10th N 1910.
5. Date and method of sowing	28th Oct. 1910, behind the country plough.	22nd Oct. 1910, behind the country plough.	4th Nov. 1910, with local drill.	8th Nov. 1910, with local drill.	12th Novem 1910, behind country plough
6. Seed rate (lbs. per acre)	60	55	82	100	60
7. Rainfall in inches — April 1st to sowing time	26·54	32·11	26·30	55·59	15·52
7. Rainfall in inches — During growth period	1·87	1·42	2·57	1·03	4·05
8. Irrigation	Twice (20th Nov. & 4th Feb. 1911).	Nil.	Three times (4th Dec. 1910, 9th Feb., 26th Feb. 1911).	Once (19th Jan. 1911).	Four times (2 Nov. 1910, 12 Feb., 8th Ma & 13th A 1911).
9. Date of harvesting	18th March 1911.	18th March 1911.	30th March 1911.	17th March 1911.	19th April 1911
10. Growth period in days	140	147	145	129	158
11. Consistency of sample — % Soft	3	7	27	62	83
11. Consistency of sample — % Intermediate	56	65	64	33	17
11. Consistency of sample — % Hard	41	28	9	5	0
12. Nitrogen percentage	2·22	2·41	1·46	1·86	1·57
13. Weight of 1,000 grains in grammes	41·75	43·75	38·87	40·60]	34·02
14. Order of merit in commercial value	First.	Second.	Third.	Fourth.	Fifth.

	Meerut.	Oral.	Partabgarh.	Dumraon.
	Heavy loam.	Typical wheat soil (*mar*).	Loam.	Sandy loam.
	Peas.	Gram.	Wheat.	*Aus* paddy removed on 1st Oct. 1910.
	Nil.	Nil.	Nil.	83 mds. cow-dung per acre applied on 22nd Oct. 1910.
	Seven ploughings with country plough (20th July, 4th & 16th Aug., 25th Sep., 18th, 23rd, 25th Oct. 1910).	Ploughed once with iron plough (21st July 1910), and scarified once with *bakhar* (16th Oct. 1910).	Five ploughings with iron ploughs (7th & 11th April, 5th May, 6th June & 7th July 1910), and five ploughings with country plough (16th July, 13th, 18th, 22nd and 23rd Oct. 1910).	Ploughed once with iron plough (10th Oct. 1910) and four times with country plough a fortnight afterwards.
	2nd Nov. 1910, behind the country plough.	6th Nov. 1910, with local drill.	24th Oct. 1910, behind the country plough.	30th Oct. 1910, behind the local drill.
	100	100	120	100
	29·23	36·50	45·21	48·96
	5·52	2·58	4·33	3·42
	Once (3rd Dec. 1910).	Once (21st Dec. 1910).	Twice (8th Dec. 1910 & 11th Feb. 1911).	Twice (17th Dec. 1910, & 13th Feb. 1911).
	14th April 1911.	27th March 1911.	10th March 1911.	14th March 1911.
	163	142	136	135
	57 26	46 37	57 32	90 9
	17	17	11	1
	1·76	1·80	1·54	1·78
	37·41	39·40	38·88	42·27
	Not tested.	Not tested.	Not tested.	Not tested.

Trial of Pusa 12 at nine stations, 1910

	Cawnpore.	Pusa.	Aligarh.	Bankipore.	Lyallpur.
1. Type of soil ..	Heavy loam.	Light loam.	Loam.	Stiff clay.	Sandy clay.
2. Previous crop ..	Cotton.	Wheat.	Cotton.	*Aus* paddy reaped on 29th Sep. 1910.	*San* ploughed in.
3. Manuring ..	Nil.	Nil.	63 mds. poudrette per acre.	Nil.	*San* ploughed on 1st Oct. 19
4. Preparation for wheat	Six ploughings with iron ploughs (14th March, 9th July, 3rd & 31st Aug., 19th Sep., 13th Oct. 1910). One ploughing with country plough (18th Oct. 1910).	Exposed several times by iron ploughs during previous hot season, afterwards fallowed.	Six ploughings with iron ploughs (8th Jan., 5th July, 27th Aug., 5th, 18th Sep. & 29th Sep. 1910). Four ploughings with country plough (28th July, 12th Oct., 24th Oct. & 30th Oct. 1910).	Eight ploughings between 4th Nov. & 6th Nov. 1910.	Harrowed on 2 Oct. 1910 a irrigated on Nov. 1910 p vious to sowi Ploughed on 1 Nov. 1910.
5. Date and method of sowing	28th Oct. 1910, behind the country plough.	22nd Oct. 1910, behind the country plough.	5th Nov. 1910, with drill.	8th Nov. 1910, with local drill.	12th Nov. 19 behind the co try plough.
6. Seed rate (lbs. per acre)	60	55	82	100	60
7. Rainfall in inches. April 1st to sowing time	26·54	32·11	26·30	55·59	15·52
7. Rainfall in inches. During growth period	1·87	1·42	2·57	1·03	4·05
8. Irrigation ..	Twice (20th Nov. 1910 & 21st Jan. 1911).	Nil.	Three times (4th Dec. 1910, 9th & 26th Feb. 1911).	Once on 19th Jan. 1911.	Four times (22 Dec. 1910, 1 Feb., 8th Ma & 13th A 1911).
9. Date of harvesting	24th March 1911.	23rd March 1911.	30th March 1911.	3rd April 1911.	19th April 191
10. Growth period in days.	146	152	144	146	158
11. Consistency of sample % Soft	0	3	4	43	88
11. Consistency of sample % Intermediate	47	80	69	46	12
11. Consistency of sample % Hard	53	17	27	11	0
12. Nitrogen percentage	1·38	2·25	2·17	1·75	1·61
13. Weight of 1,000 grains in grammes	40·81	42·64	37·25	40·78	35·53
14. Order of merit in commercial value	First.	Second.	Third.	Fourth.	Fifth.

-11.

	Meerut.	Orai.	Partabgarh.	Dumraon.
	Heavy loam.	Typical wheat soil (*mar*).	Loam.	Loam.
	Peas.	Gram.	Wheat.	*Aus* paddy harvested on 1st Oct. 1910.
in 10.	Nil.	Nil.	Nil.	83 mds. cow-dung applied on 20th Oct. 1910.
9 a 5th 2nd 5th (re- ag. th	Seven ploughings with the country plough (20th July, 4th & 16th Aug., 25th Sept., 18th, 23rd & 25th Oct. 1910).	Ploughed once with iron plough on 21st July 1910 and cultivated once with the *bakhar* on 16th Oct. 1910.	Ploughed five times with iron ploughs (7th & 11th April, 5th May, 6th June, 7th July 1910), and five times with the country plough (16th July, 13th, 18th, 22nd & 23rd Oct. 1910).	Ploughed once with iron plough on 10th Oct. 1910, four times with native plough (24th & 25th Oct. 1910).
10, m-	2nd Nov. 1910, behind the country plough.	6th Nov. 1910, behind the country drill.	24th Oct. 1910, behind the country plough.	30th Oct. 1910, with local drill.
	100	100	120	100
	29·23	36·50	45·21	48·96
	5·52	2·58	4·33	3·42
nd 5th ch ril	Once on 3rd Dec. 1910.	Once on 21st Dec. 1910.	Twice (8th Dec. 1910 & 11th Feb. 1911).	Twice (17th Dec. 1910 & 13th Feb. 1911).
	14th April 1911.	27th March. 1911.	22nd March 1911.	2nd April 1911.
	163	142	148	154
	7	30	55	86
	92	42	27	13
	31	28	18	1
	1·51	1·66	1·56	1·75
	35·03	38·68	38·03	38·15
	Not tested.	Not tested.	Not tested.	Not tested.

Trial of Pusa 22 at nine stations,

	Cawnpore.	Pusa.	Aligarh.	Bankipore.	Lyallpu
1. Type of soil ..	Heavy loam.	Light loam.	Loam.	Stiff clay.	Sandy loam.
2. Previous crop ..	Wheat.	Wheat.	Cotton.	*Aus* paddy reaped on 29th Sep. 1910.	*San* ploughed
3. Manuring ..	Nil.	Nil.	63 mds. poudrette per acre.	Nil.	*San* ploughed 1st October,
4. Preparation for wheat	Six ploughings with iron plough (5th May, 10th July, 4th Aug., 1st & 20th Sept., 14th Oct. 1910). Once with country plough (18th Oct. 1910).	Exposed by iron ploughs during previous hot season, afterwards fallowed.	Five ploughings with iron plough (17th Dec. 1909, 6th Jan., 5th Aug., 5th & 17th Sep. 1910), four ploughings with country plough (28th July, 12th, 24th & 30th Oct. 1910).	Eight ploughings between 4th and 6th Nov. 1910.	Harrowed on Oct. and ri ed on 5th 1910 previo sowing. Plou on 10th 1910.
5. Date and method of sowing	30th Oct. 1910, behind the country plough.	28th Oct. 1910, behind the country plough.	5th Nov. 1910, with drill.	8th Nov. 1910, with local drill	12th Nov. 19 hind the co plough.
6. Seed rate (lbs. per acre)	60	55	82	100	60
7. Rainfall in inches — April 1st to sowing time	26·54	32·11	26·30	55·59	15·52
7. Rainfall in inches — During growth period	1·87	1·42	2·57	1·03	4·05
8. Irrigation ..	Three times (21st Nov., 17th Dec. 1910, 5th February 1911).	Nil.	Three times (9th Dec. 1910, 9th & 26th Feb. 1911).	Once (19th Jan. 1911).	Four times (Nov. 1910, Feb., 8th M and 13th 1911).
9. Date of harvesting	26th March 1911.	26th March 1911.	31st March 1911	5th April 1911	20th April 19
10. Growth period in days	148	149	145	148	159
11. Consistency of sample — % Soft ..	0	5	3	26	91
11. Consistency of sample — % Intermediate	25	34	45	53	9
11. Consistency of sample — % Hard ..	75	61	52	21	0
12. Nitrogen percentage	1·91	1·97	1·55	1·70	1·74
13. Weight of 1,000 grains in grammes	34·80	30·12	28·58	32·20	25·42
14. Order of merit in commercial value	First.	Second.	Third.	Fourth.	Fifth.

1910-11.

R.	Meerut.	Orai.	Partabgarh.	Dumraon.
	Heavy loam.	Typical wheat soil (*mar*).	Loam.	Loam.
in.	Peas.	Gram.	Wheat.	*Aus* paddy harvested on 1st October 1910.
in on 1910.	Nil.	Nil.	Nil.	83 mds. of cowdung applied on 22nd Oct. 1910.
29th rigat- Nov. us to ghed Nov.	Seven ploughings with country plough (20th July, 4th & 16th Aug., 25th Sep., 18th, 23rd & 25th Oct. 1910).	Ploughed once with iron plough on 21st July 1910 and cultivated once with the *bakhar* on 16th Oct. 1910.	Five ploughings with iron plough (7th & 11th April, 5th May, 6th June, & 7th July 1910), five ploughings with country plough (16th July, 13th, 18th, 22nd & 23rd Oct. 1910).	One ploughing with iron plough (10th Oct. 1910), four ploughings with country plough on 24th and 25th Oct. 1910.
0, be- untry	2nd Nov. 1910, behind the country plough.	6th Nov. 1910, behind the country plough.	24th Oct. 1910, behind the country plough.	30th Oct. 1910, with local drill.
	100	100	120	100
	29·23	36·50	45·21	48·96
	5·52	2·58	4·33	3·42
22nd 16th arch, April	Once (3rd Dec. 1910).	Once (21st Dec. 1910).	Twice (8th Dec. 1910, 11th Feb. 1911).	Twice (17th Dec. 1910, 13th Feb. 1911).
11.	14th April 1911.	5th April 1911.	22nd March 1911.	2nd April 1911.
	163	151	148	154
	5 30	1 33	53 29	53 34
	65	66	18	13
	1·79	1·83	1·63	1·68
	25·58	26·25	29·70	26·07
	Not tested.	Not tested.	Not tested.	Not tested.

Trial of Pusa 4 at P

		P
1.	Type of soil	Light loa
2.	Previous crop	Wl
3.	Manuring	Ni
4.	Preparation for wheat ..	Exposed times plough previ seas wards
5.	Date and method of sowing	22nd behi country
6.	Seed rate (lbs. per acre) ..	80
7.	Rainfall in inches — April 1st to sowing time	32
	Rainfall in inches — During growth period	1
8.	Irrigation	N
9.	Date of harvesting ..	16th Ma
10.	Growth period in days ..	144
11.	Consistency of sample — % Soft ..	0
	Consistency of sample — % Intermediate ..	9
	Consistency of sample — % Hard ..	91
12.	Nitrogen percentage ..	2
13.	Weight of 1,000 grains in grammes	4
14.	Order of merit in commercial value	F

lusa and Raipur, 1910-11.

...SA.	RAIPUR (dry).	RAIPUR (irrigated).
...m.	Black, moisture retentive clayey loam (*kanhar*).	Black moisture retentive clayey loam (*kanhar*).
...eat.	Wheat.	Wheat.
...l.	Nil.	Nil.
... several ... by iron ... during ... ous hot ... n, after- ...allowed.	Scarified six times with the *bakhar*.	Scarified six times with the *bakhar*.
...ct. 1910, ...nd the ...y plough.	4th Nov. 1910, with *Nari* plough.	4th Nov. 1910, with *Nari* plough.
	·80	80
·11	64·64	64·64
·42	2·12	2·12
...l.	Nil.	Twice.
...rch 1911.	23rd Feb. 1911.	23rd Feb. 1911.
	·111	111
	0	3
	50	69
	50	28
·25	1·79	1·81
·67	45·30	44·66
...rst.	Second.	Third.

Raipur is situated in the Chattisgarh Division of the Central Provinces and is characteristic of the black, moisture-retaining soils of this part of India. The three most important stations of North-Western India are Cawnpore, Aligarh and Lyallpur. At all these the crop is grown by means of canal irrigation, and all are situated in tracts, which, at the present time, grow large quantities of weak wheats like Muzaffarnagar for the export trade. It is sometimes stated that high quality wheats cannot be grown under canal irrigation in Northern India so that the results of the present trials are of particular interest.

The cultivation details relating to these various samples are given in the tables, and the results of the milling and baking tests are dealt with in full below. As the cost of milling and baking the whole thirty-six samples would have been very great, a selection had to be made, and for this purpose Cawnpore, Pusa, Aligarh, Bankipore, Raipur and Lyallpur were chosen.

REPORT BY MR. A. E. HUMPHRIES (PAST PRESIDENT OF THE NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS) ON TWENTY-FOUR SAMPLES OF INDIAN WHEAT, GROWN IN 1911.

"In each of the last three years, I have tested and furnished a report upon various sample lots of Indian wheat sent to me by the Indian Government for that purpose. In those reports, I have discussed many points concerning the qualities and commercial value of wheat and wheaten flour, which I need not repeat at length herein. It may, however, be desirable to summarise a few of them.

By the term strength I mean the capacity for making large, shapely, well aerated loaves, by stability the facility with which large masses of dough can be handled in the bakehouse. Good flavour implies a pleasant moistness and slight sweetness in bread at least one day old. Good colour means brightness of appearance, associated either with whiteness or with a slight yellowness. Dinginess is bad whatever the hue may be, and yellowness must be slight, if the flour or bread is to be highly esteemed for colour. The capacity for making a large quantity of bread from

a given quantity of flour is another unit of quality, separate and distinct from strength or stability, and having regard to the fact that in all these tests, I am dealing with small quantities of wheat, I have made no attempt to determine the relative merits of these sample lots on this point.

The colour of the bran does not necessarily indicate the colour of the endosperm; wheat with a red skin may yield a very white flour, or a wheat with a white skin may yield a very yellow flour. Nor is a red wheat necessarily or even probably stronger than a white one; but inasmuch as white bran is generally more valuable as a commercial commodity than red bran, also because powdered white bran is less discolouring than powdered red bran, and as in grinding, some of the husk always is powdered, white wheat is better than red wheat, if on all other points they are actually or approximately equal. But on the other hand, the growing of red wheat need not be discouraged if there be any valid general or local reasons for preferring some existing red varieties, or if there should be any prejudice in some parts of India in favour of red wheat.

British millers do not object to hardness in ordinary wheat (*T. vulgare*) nor do they object to mellowness, so long as the wheat is free-milling. They very strongly prefer wheat which can be easily separated into its commercial constituents, so that the bran can be removed with a minimum of grinding, and the flour be separated with a minimum of trouble in dressing.

Relative commercial values depend upon supply and demand and strong wheats are ordinarily in relatively small supply and command higher prices than weak wheats. But there will always be a demand for some weak wheats, from which flours most suitable for the manufacture of biscuits or puddings can be produced, or which can be mixed with very strong wheats for the production of many typical British bread flours. From these premises it follows that the difference in commercial value between strong and weak wheats is not a constant one, but does and will vary from time to time as the relative supply of each type varies. On the average

of seasons, however, strong wheats are likely to command substantially higher prices than weak ones.

All Indian wheats possess stability in a high degree, that is to say, the baker handling large masses of dough produced from flour obtained from Indian wheats only, is not at all troubled by stickiness or kindred faults, but some of the new varieties possess in addition to that good point, the toughness and resilience of dough characteristic of American or Canadian Spring wheats. This improvement and increase in strength as herein defined, can be developed by skilful wheat conditioning and by the use in baking of malt extracts possessing high diastatic power. Some wheats possess potentialities which can be developed in this way, others do not.

I have received for testing this year five varieties of wheat:—

Muzaffarnagar.
Pusa 8.
Pusa 12.
Pusa 22.
Pusa 4.

Each of the first four varieties was grown at five places—

Aligarh.
Bankipore.
Cawnpore.
Lyallpur.
Pusa.

One of the varieties (Pusa 22) was also grown at Pusa on land which had been waterlogged. Of these four varieties, I therefore received twenty-one lots. I also received three lots of the variety Pusa 4; one grown at Pusa, another at Raipur on unirrigated land and another at Raipur on irrigated land. All of these twenty-four sample lots were white wheat.

I have cleaned, conditioned, milled and baked each one separately. It was necessary to clean them, because the samples from Lyallpur, and in lesser degree the samples from Pusa were dirty. They appeared to have been subjected to unfavourable

climatic conditions during harvesting or threshing. However, I was able to remove that blemish by washing and scouring.

Investigations I have made in the last twelve months and recorded at the Portsmouth Meeting of the British Association, show that wheat conditioning brings about small but fundamental changes in the constitution of the flour. I have, therefore, amplified my usual programme for conditioning such sample lots, and have sought in still greater degree to give each lot the degree of conditioning it required. With that object, I conditioned them all slightly at the outset and then increased the percentage of added water in those cases which would be improved by the addition. As a result of this part of the investigation, the Muzaffarnagars and Pusa 8 received much less conditioning water than the others. A very great, indeed I may say an extraordinarily great improvement was brought about in Pusa 22 in this way, and substantial improvements were made in Pusa 12 and Pusa 4.

I baked almost all of them four times each. For the first two trials in each case, I used flour, water, salt and yeast only. Almost invariably Indian wheat is mixed by British millers with other kinds, so in the second round of baking trials, I used a typical British flour milled from a mixture of several wheats, foreign and English, taking in each case 50% of that flour and adding 50% from each sample lot of Indian. For the third round, I used a very small percentage of malt extract and grouped the flours according to the place where the wheats had been grown. For the fourth round, I again used the malt extract and reverted to the grouping of flours according to the variety of the wheats.

Following my usual custom, I examined each sample by eye before milling: a method which is, of course, used by millers in buying wheat, especially the first lot of any new kind. Having finally written down all the data upon which I should form opinions, I then referred to previous reports to see in what way results had been affected by seasonal, or agricultural causes in India, or any other way.

Muzaffarnagars.

All these five lots are typical of the variety, and I need not describe them in detail. In previous years, I have received among a larger number of Muzaffarnagar samples, consignments raised at the five centres from which this year's sample lots came. Judged by appearance and aided by reference to former reports I find the following interesting comparisons can be made concerning the order of merit in each season :—

1909.	1910.	1911.
Cawnpore.	Pusa.	Cawnpore.
Pusa.	Cawnpore.	Pusa.
Aligarh.	Aligarh.	Aligarh.
Bankipore.	Bankipore.	Bankipore.
Lyallpur.	Lyallpur.	Lyallpur.

In 1909, the samples represented great differences in money value. In 1910, those differences were much smaller. This year they are again relatively small. The Cawnpore lot is of very pleasing appearance, very good indeed of its kind. Pusa is not much behind it in appearance. The Lyallpur lot was dirty, but apart from that unfortunate and presumably avoidable blemish it is substantially as good in appearance as the Aligarh and Bankipore lots. This variety should not be heavily conditioned, and if that precaution be observed, it can be milled satisfactorily. There was no appreciable difference between the five lots concerning that stage of my investigation. Judged by their behaviour in the bakehouse, the differences are substantial but not great. Cawnpore and Pusa are very close together at the top, Bankipore and Lyallpur at the bottom, so that their relative values, judged by appearance, are a correct index of their baking values.

The Lyallpur loaves possessed a crust characteristic of Rivet wheat, one of our commonest English varieties, and more nearly resembled the ordinary Kurrachee wheats of commerce than any other sample. From this remark it may be inferred that the other four lots are superior in baking value to ordinary Kurrachee wheat.

The presence of translucent berries improves the appearance of a sample according to usual ideas concerning commercial excellence, but that causes the flour obtained from such lots to be brighter and more yellow, or at least less white than that produced from lots of the same variety which contain no translucent berries. So whereas the bread produced from this Lyallpur lot was worse in colour and general appearance than the others, the flour itself was relatively white in hue, and therefore, quite as well fitted for the making of puddings and biscuits as the substantially better lots from Cawnpore and Pusa.

I need not refer in detail to my previously expressed opinions concerning this variety. For certain purposes and under certain conditions it yields good flour, but for modern requirements of actual milling and for the making of bread, either of the other varieties sent me this year are much better having regard to their behaviour at all five places.

Pusa 8.

In some respects this wheat is not unlike Muzaffarnagar, and the similarity is more apparent in the lots grown at Bankipore and Aligarh than in others. The Lyallpur lot has a dusty, dingy appearance and has a black spot at the germ end of the berry. This last named blemish occurs also in the Pusa sample, and to a very slight extent in that grown at Cawnpore. However, that does not seem to damage the flour and need not be regarded as a serious fault. The Cawnpore has the appearance of strength and so has the Pusa lot, but in lesser degree. The others look weak, that from Lyallpur decidedly so. According to appearance the five lots should be placed in the following order of merit :—

Cawnpore.
Pusa.
Aligarh.
Bankipore.
Lyallpur.

In milling, this variety behaves similarly to Muzaffarnagar, possessing as it does the same typical mellowness, so that for optimum results it does not require and will not satisfactorily respond to much conditioning. But there the similarity ends so far as my work is concerned. In the bakehouse the Pusa and Cawnpore lots show a most decided superiority to those from Aligarh, Bankipore and Lyallpur. Both yield tough doughs, the Pusa lot particularly, and from both lots fine large loaves can be obtained. There is a superiority in the other three lots over the Muzaffarnagar grown at the same places, but they all yield the same type of flour. When by lapse of time the conditioning had worked its full effect and when malt extract was added in baking, the Pusa lot behaved very much like Russian Ghirka wheat, and this of itself is noteworthy. The bakehouse results, in the case of this variety also, leave the order of merit unchanged from that assigned to them by their appearance, but the Pusa and Cawnpore lots are very close together, and at a considerable distance the other three lots are also close together.

Pusa 12.

This variety also resembles Muzaffarnagar in appearance, and it is free from the black spot at the germ end of the berry which is seen in some samples of Pusa 8. It can be described as a mellow wheat, but it differs from Muzaffarnagar and in lesser degree from Pusa 8, because its baking qualities are improved, and its behaviour in the milling processes is not prejudicially affected by the addition of water in conditioning, even if that process be applied severely. The five samples, judged by appearance, are in the following order of merit:—

Cawnpore.
Pusa.
Aligarh.
Bankipore.
Lyallpur.

and the differences between them are great, for the Cawnpore lot is a very beautiful sample, and the Lyallpur a distinctly poor one. Stated in money value, the difference is from half a crown to three shillings per quarter. The Pusa sample is a good one, and so are the Aligarh and the Bankipore lots, but in the cases of this variety, the differences between each lot are approximately equal, the best being very good, the worst distinctly poor. I find, however, this important difference in baking value. In the cases of Muzaffarnagar and Pusa 8 already dealt with, the differences disclosed by baking tests are substantial. In this case, the baking results tally in order of merit with my judgment as to appearance, but the differences are not large. This really means that the Aligarh, Bankipore and Lyallpur lots bake out really well. From the last named, we did not obtain a tough dough, but in increasing degrees from all the others we do so, and a baker who has to handle large masses of dough regularly for stability would very much prefer Pusa 12 flour to Muzaffarnagar and in lesser degree to Pusa 8.

Pusa 22.

This variety differs greatly on several points from Muzaffarnagar, Pusa 8, and Pusa 12. The berries are comparatively short and would be described in technical phrase as round or short-berried, whereas the others would be described as long-berried. It is distinctly hard by nature whereas the others are mellow. I have not hereinbefore used the terms woolly and its technical opposite free-milling, which I explained at length in previous reports, but I may say at this stage that whereas Muzaffarnagar and Pusa 8 are mellow and either slightly or markedly woolly in texture (in other words possess physical characteristics which prevent the miller from making separations of branny husk from kernel easily), the Pusa 12 is mellow and free-milling; and Pusa 22 is hard and free-milling. Furthermore, the addition of water in conditioning to Pusa 12 improved its baking qualities and was not required to improve its behaviour in the milling processes; but in the case of Pusa 22, the conditioning was desir-

able for both reasons and brought about a remarkable change. All these lots contained a comparatively low percentage of water when I made the first round of milling tests. When the flours obtained from that round were baked, Pusa 22 gave a surprising result, for I knew that it was White Jana Khar which, in 1909, yielded flour of the highest class, possessing among other first rate characteristics a really great strength; yet from the first milling this season we obtained flour which was not strong, though first rate in other respects. Finally, after some experimenting, I raised the water content of the wheat to high figures, and then let some part of it remain for a considerable time before it was milled. Then we obtained results in the bakehouse similar to those of 1909, and the behaviour of the variety during the milling processes of grinding and dressing was first rate. Even so, I have not this year obtained quite so good baking results as in 1909, but the miller and baker would be extremely hard to please if they were not content with them even this year. Judged by appearance, we again get the same order of merit as in the previous cases stated herein—

Cawnpore.
Pusa.
Aligarh.
Bankipore.
Lyallpur.

with this difference, that the Pusa and Aligarh lots should be bracketed equal. Furthermore, the appearance of these wheats provided a forecast of some of the baking results already specified, for though the Cawnpore lot looked strong, the others did not this season appear to be nearly so strong as the one lot of this variety which I received in 1909. All of them are really good as regards stability, and the order of merit on that point of quality agrees with their appearance as recorded above. In that respect they stand well in competition with wheat from any part of the world and the Cawnpore lot gets into the very highest class. As regards the one point of strength (size of loaf) the results are not so good, and all five lots

are close together, but taking all points of quality into consideration the results are very good indeed. The extra lot from Pusa, grown on land which had been waterlogged, contained a substantial proportion of shrivelled or imperfectly developed grain, and this would reduce its commercial value 6*d.* to 9*d.* per quarter below that of the Pusa lot grown under normal conditions. Apart from that there is practically no difference between the two samples. The preference would be given to the normally grown lot on the other points of quality, but it would be a preference only, representing no further difference in commercial value.

Pusa 4.

All three samples of this variety (Pusa, Raipur unirrigated and Raipur irrigated) are in the category of hard, free-milling wheats. The Raipur unirrigated lot is truly superb in appearance, indeed I do not think I am exaggerating if I say, it is the finest looking lot of Indian wheat I have ever seen. The Raipur irrigated is distinctly inferior to it in appearance, but is nevertheless a very beautiful sample. The lot from Pusa suffers by the comparison. It contains some damaged corns and is dingy in appearance. The black spot at the blunt or germ end of the berry occurs this year again in this lot, and it is a blemish, though not a serious one. Nevertheless this lot appears to be strong and is so, in fact as well in appearance. Unfortunately, I received only comparatively small quantities of this variety, so have not been able to make extended baking tests with it. But the results I did obtain were good. In hue, and general appearance of crust and crumb, the Raipur lots are of the very highest class, but on the one point of strength they are really good without being extraordinary judged by the standard of typical London flour. The Pusa lot is, however, extremely good on all points including strength, in other words, is better than it looks. A miller buying the wheats for the first time on appearance only would unhesitatingly place the Raipur unirrigated lot not only at the head of the Pusa 4 variety, but of the entire lot I have received this season; but having milled and baked them under the conditions

described herein, I should myself choose the Pusa 4 lot grown at Pusa for that position.

The Wheats grown at Pusa.

In previous years I have reported very favourably on wheats of the Pusa Nursery group, that is to say, on new varieties obtained by selection or hybridizing at Pusa. I had also noted that, as a rule, any variety grown at that centre behaved better than the same variety grown elsewhere. So I recommended that wheats of the Pusa Nursery group should be tried at several centres before a final opinion as to their degree of superiority should be given. I was, therefore, pleased to see that the Economic Botanists at Pusa and Cawnpore had by their action anticipated my recommendation, rendering it possible to see how some of the varieties behaved at several places in India. It is very well known that no variety is likely to suit all environments. This is abundantly evident in the United Kingdom, much more is it likely to be so in a country of great distances like India. I have, therefore, in dealing with this year's consignment of twenty-four samples examined them not only by groups according to variety, but also by groups according to their place of origin, and I desire to make the following remarks upon the last named classification. It will have been seen how extremely uniform the order of merit is this year in the case of all varieties. I have received no information directly or indirectly as to the climatic conditions prevailing this year at Pusa during the maturation, harvesting and threshing of its wheats, but I should suppose from the appearance of the samples that those climatic conditions must have been relatively unfavourable. However, as a miller with considerable experience, I am used to evidences of such mishaps and probably differ from the grower or merchant in appraising their importance. That is the reason why I have again placed the wheats grown at Pusa so highly according to appearance. But the baking results confirm my opinions based on appearance and I need at this juncture merely consider how, as regards quality, each of the five varieties suits the environment furnished by Pusa.

Judged by appearance the blemishes already mentioned, kept Pusa 4 from the first place. For that position Pusa 8 and Pusa 12 could be bracketed. Then I placed Pusa 4, with Pusa 22 and Muzaffarnagar following. But milling and baking trials upset that order, and in spite of its blemishes, Pusa 4 goes to the top and the order of merit is this :—

Pusa 4.
Pusa 8.
Pusa 12.
Pusa 22.
Muzaffarnagar.

Cawnpore Wheats.

I suppose the climatic conditions at this centre must have been excellent for all four varieties grown there are of beautiful quality and appearance. I received no sample of Pusa 4 from Cawnpore or the places remaining to be mentioned. On appearance the order of merit is simple, for I bracketed Pusa 12, Pusa 8 and Pusa 22 equal, then the Muzaffarnagar. The milling and baking tests, however, sort them out and the order of merit then is,—

Pusa 12.
Pusa 8.
Pusa 22.
Muzaffarnagar.

The Pusa 12 and Pusa 8 are distinctly superior to the other two varieties at this centre.

Aligarh Wheats.

In no case is the Aligarh sample equal either to the Cawnpore or Pusa lot, but appearances and the milling and baking tests agree in revealing substantial differences and the order of merit is—

Pusa 12 } equal.
Pusa 22 }
Pusa 8.
Muzaffarnagar.

In this case the Muzaffarnagar is not far below Pusa 8.

Bankipore Wheats.

In this case also appearances and the milling and baking results agree. The differences though appreciable are not so great as in the former cases, and each sample is pale in flour.

The order of merit is—

Pusa 12 } very nearly equal.
Pusa 22 }
Pusa 8.
Muzaffarnagar.

Lyallpur Wheats.

Believing that this centre represents a district in which a large quantity of Muzaffarnagar is grown, I have been curious to see how the comparison would come out. When examining these wheats by appearance, I dictated the following note :—

"Muzaffarnagar is the best looking, the others are so dingy and generally poor, that on appearance nobody would give more for them. They may be slightly stronger, but from appearance Muzaffarnagar is the best wheat grown at this station, and there is practically nothing between the others." I shall be glad to learn in due course whether the climatic conditions during harvesting or threshing were alike for all four varieties; whether for instance the Muzaffarnagar ripened earlier or later than the others, and so escaped some bad weather from which the others suffered; alternately whether they were threshed under comparable conditions. If the former alternative be the reason why the three new varieties appear to be relatively poor in appearance, it will be interesting to know whether the unfavourable conditions are likely to occur in other seasons, or whether they are merely an accident of the last one.

In the milling processes Muzaffarnagar is rather better than Pusa 8, but inferior to Pusa 12 and Pusa 22. In the bakehouse the effects of superior breed triumph, as they usually do, over other influences under such conditions as these, so on baking results the order of merit is this :—

Pusa 12.
Pusa 22.

Pusa 8.
Muzaffarnagar.

and the differences are substantial.

I believe that Sir James Wilson has advocated in public the separate marketing of Muzaffarnagar wheat, and I certainly endorse his recommendation and extend it. It can readily be understood that the shipping of great quantities of wheat from one port is facilitated by making up a commercial type upon which a very great business can be transacted, but, on the other hand, the later developments of milling have intensified the importance of treating each wheat according to its individual requirements. Choice white Kurrachee is a mixture of two principal types of wheat, one (principally Muzaffarnagar) mellow and woolly, the other hard and free-milling kinds. No miller can make the best of both kinds when he receives them mixed together. He may desire or be perfectly willing to buy both, but if sellers wish to make the most of such widely differing wheats, they must, by offering them separately, put the miller in a position to treat each one to the best advantage. I do not wish to advocate any extreme course, or I should say that it would be wise to keep Muzaffarnagar and Pusa 8 separate, if the latter should be grown to a substantial extent in the Punjab or United Provinces, but bearing in mind the exigencies of a large export business, I would as a practical proposition be content to see these two varieties grouped together for export, but if Pusa 12, or more emphatically if Pusa 22 be largely grown in districts supplying the port of Kurrachee, the recommendation to keep them separate from Muzaffarnagar is important.

Summary.

The results I have obtained again demonstrate the well-known fact that differences in soil, climate and water-supply do materially affect the quality of wheat. I need not emphasize that point now. But another point is equally apparent from these tests; that the inherent and hereditary influences of breed are extremely important,

perhaps predominant. The following table will illustrate the point omitting for this purpose Pusa 4 altogether :—

	Pusa 12.	*Pusa* 22.	*Pusa* 8.	*Muzaffarnagar.*
Aligarh ..	1	1	3	4
Bankipur ..	1	1	3	4
Cawnpore ..	1	3	2	4
Lyallpur ..	1	2	3	4
Pusa ..	1	3	1	4
	5	10	12	20

In this table I have set out the order of merit indicated by milling and baking tests, and the figures at the bottom of each column show how on results so obtained, Pusa 12 comes out top with Pusa 22 and Pusa 8 close together and Muzaffarnagar last. The additions are made merely to indicate the order of merit and not their relative degrees of excellence. For my own guidance, I have recorded results in marks and the addition of them, grouped according to variety, yields the same order of merit. I have already shown that the differences between the varieties are not the same at all centres, but the broad principle comes out clearly from these tests that the effect of breed is predominant or at least is extremely important. I do not think, however, that any one variety will be equally suitable for all those parts of India in which ordinary wheat (*T. vulgare*) is or can be grown, and I should like to see these tests continued and extended to other varieties.

I should also like to repeat the opinion expressed in my previous reports, that the financial return to the grower should be the predominant influence in determining the suitability of any or all varieties of wheat in India as elsewhere. British millers are likely to pay relatively high prices for the wheats I have tested, compared with the existing typical Kurrachee and Calcutta wheats exported, and this remark includes Muzaffarnagar also, for that can be used satisfactorily for special purposes, and is for them more valuable than ordinary Choice White Kurrachee, or No. 2 Club, Calcutta ;

but British millers are not likely to pay an increased price sufficient to compensate the grower for a substantially diminished yield. Furthermore, British millers are in a better position than ever they were to make the best use of any and every kind of wheat offered them, provided widely differing kinds are sold separately and not mixed together.

It seems to me, that this year's results are most encouraging to all concerned in the work. I have been compelled in handling small quantities of wheat to use methods of milling inferior to those used in ordinary milling plants worked commercially, but the bake-house results I have obtained are astonishingly good as regards the colour and general appearance of the bread obtained, and judged on all points of quality any one of these wheats, Muzaffarnagar included, provided the precautions I have specified are observed, are on the whole much superior to those obtained from ordinary Indian wheats milled on a commercial scale, and as we have seen, the newer varieties are superior for bread making to Muzaffarnagar. I should especially like to see Pusa 4 tested extensively, and the cause for its small black spot blemish investigated. On balance of points, I selected it from last year's set of samples for special comparison with Manitoba wheat, and most certainly it is a variety which should be carefully watched and tested as one of several likely to be very useful in providing first class and much improved wheat for export to Great Britain."

WEYBRIDGE, ENGLAND.
The 29th November 1911.

A. E. HUMPHRIES.

Several very interesting results are to be found in this report which it is proposed to deal with briefly. The first relates to the tests of the Muzaffarnagar samples which are summed up in the table following (see page 87). These behaved in 1911 practically like those

Comparative value of Muzaffarnagar white grown at Nine Stations in 1908-09, 1909-10 *and* 1910-11.

Where grown.	Consistency.									Weight of 1,000 grains in grammes.			Nitrogen percentage.			Bakers' marks.				Order of merit in commercial value.		
	1908-09.			1909-10.			1910-11.									1908-09.		1909-10.				
	Soft.	Inter.	Hard.	Soft.	Inter.	Hard.	Soft.	Inter.	Hard.	1908-09.	1909-10.	1910-11.	1908-09.	1909-10.	1910-11.	Stability.	Strength.	Stability.	Strength.	1908-09.	1909-10.	1910-11.
Cawnpore ..	8	48	39	5	72	23	3	58	39	35·69	38·07	34·18	2·37	1·79	1·93	84	75	72	62	First	Second	First
Pusa ..	16	59	25	0	57	43	0	72	27	38·35	39·80	33·03	2·00	2·19	2·05	84	75	80	72	Second	First	Second
Partabgarh ..	36	33	31	50	38	12	27	61	12	40·02	39·71	34·18	1·79	1·49	1·43	82	75	70	62	Third	Third	..
Meerut ..	..	..	..	54	30	16	15	65	20	..	37·92	30·52	1·34	1·79	1·75	70	60	70	62	Sixth	Fourth	..
Aligarh ..	76	15	9	57	35	8	42	45	13	42·54	34·58	28·84	1·30	1·60	1·34	70	60	70	62	Fifth	Fifth	Third
Orai ..	95	5	0	66	29	5	44	49	7	30·97	37·65	31·18	1·93	1·45	1·44	64	60	72	62	Ninth	Sixth	..
Bankipore ..	83	13	4	79	14	7	60	35	5	38·95	42·58	35·51	1·34	1·48	1·46	68	52	72	62	Seventh	Seventh	Fourth
Dumraon ..	72	21	7	58	36	6	63	29	8	43·67	40·73	29·05	1·52	1·41	1·65	78	63	72	62	Fourth	Eighth	..
Lyallpur ..	75	20	5	78	16	6	85	15	0	37·08	40·47	36·15	1·52	1·38	1·43	68	68	70	62	Eighth	Ninth	Fifth

In 1910-11 no bakers' marks were awarded and only five wheats were tested.

of the previous year, and it is clear that little or no further differences are likely to be obtained by the continued trial of this wheat. In the three seasons, 1909 to 1911, the order of merit in commercial value has been almost the same with Cawnpore and Pusa at the top followed by Aligarh and Bankipore with Lyallpur last. In no case has this wheat become strong, it has always remained a weak wheat with somewhat inferior milling qualities but when grown to perfection at Cawnpore and Pusa the sample has been improved in appearance, and has done better in the mill and bakehouse. This indicates, as would be expected, that in the maintenance of quality the methods of growing wheat are of some importance. As regards further work with this wheat it is proposed in 1912-13 to grow all the Muzuffarnagars from each centre side by side at Aligarh and to compare the resulting samples. It is probable that the environmental differences will disappear and that the seed from all the plots will be identical.

The chief result contained in the report relates to the behaviour of the strong wheats at the various centres and it is clear that no matter how unfavourable the conditions were under which the wheats were grown quality has not been lost. The results confirm those of Humphries and Biffen in England.[1] These investigators grew two wheats, differing in strength, on seven types of soil and found that while the soil had a considerable influence on the strength yet on all soils the stronger variety, Red Lammas, gave the better result. The results also confirm the English experience with Fife and its hybrids which yield strong flour. Fife wheat has retained its strength and high qualities even in England where the great majority of the wheats now grown are exceedingly weak.

In considering the results obtained with these strong wheats at the various stations in the plains the behaviour of Muzaffarnagar at Pusa and Cawnpore must be borne in mind. At these centres during the past few years a considerable amount of attention has been paid to the manner of growing wheat and to the conditions

1 Humphries & Biffen, *l. c.*

under which optimum results, both as regards yield and quality, can be obtained. Under these conditions Muzaffarnagar has improved in quality. In the case of the strong wheats the best results were also obtained at Cawnpore and Pusa after which those at Aligarh follow in order of merit. At Bankipore the wheats were grown after rice the same year with a hurried preparation for the wheat crop. As will be evident from the results described in the next section of this paper such a preparation for wheat was the worst that could be devised. In spite of this, however, the strong wheats did not lose their qualities. At Lyallpur the preparation was distinctly inferior to that at Cawnpore and in addition the crop was watered four times. On the alluvium this kind of preparation and treatment of the crop is very detrimental and optimum results are not possible in this way. Even at this centre the milling and baking qualities asserted themselves and the strong wheats did best. Had the preparation at Bankipore and Lyallpur been equal to that at the other stations it is certain that the samples would have given still better results. To sum up the report, Pusa 12 proved the strongest wheat and did best at all stations producing good loaves even under adverse conditions. This wheat, in addition to its good quality is also a heavy yielder which is interesting in view of the statements often made that yield and quality in the same wheat cannot be combined. As regards stations, the best results were obtained at Cawnpore under canal irrigation, thus disposing of the idea that strength and high milling qualities are only possible under *barani* conditions at stations like Pusa.[1] The Cawnpore results are of particular importance in this matter as they prove that very fine samples of wheat of high quality and appearance can be grown under canal irrigation provided the cultivation is suitable and the amount of water is regulated. Similar samples were produced in 1910 and again in the present year, 1912.

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[1] The results obtained in 1911 with the Pusa samples were slightly inferior to those at Cawnpore. At the former station the climatic conditions in 1911 were relatively unfavourable. The soil moisture was deficient and rain, wind and fog, followed by hot winds just before harvest, did considerable damage to the crop.

At Raipur, the black soil station, the only strong wheat tested was Pusa 4. This was grown as a dry crop and also irrigated. The appearance of the Raipur samples was exceedingly fine and equal to any of the wheats that have ever been grown at Pusa. The grains were large with an absolute weight of over 45 grammes and in the milling and baking tests Mr. Humphries said: "In hue and general appearance of crust and crumb the Raipur lots are of the very highest class, but on the one point of strength they are really good without being extraordinarily judged by the standard of typical London flour." This is a most important result in a tract which produces so much weak soft wheat and it indicates that on the black cotton soils of the Peninsula wheats of considerably higher quality than those now cultivated can be grown to perfection. In the black soil tracts of the Central Provinces the yield of wheat is always low, anything over twelve bushels to the acre being very exceptional. The intractable nature of the soil and the difficulty in keeping the soil moisture near enough to the surface of the ground to promote tillering are adverse factors to any great increase in the yield. As is well-known the chief factor determining the yield of wheat is the amount of tillering. If the soil conditions are such that very little tillering can take place it is impossible to get heavy yields. Further, the shortness of the season is another factor operating in the same direction. To obtain even the present yields as much as 100 lbs. of seed to the acre has to be sown, so that the net increase per acre is not great and rarely exceeds 600 lbs. to the acre. In these tracts the plant breeder will find great difficulties in his path if yields like those easily possible in the plains are desired. With quality, however, the matter is quite different, and it is in this direction that the greatest chance of improvement lies. That this is a likely avenue of progress is proved by the Raipur results with Pusa 4 in 1911 which in addition to good quality also gave a very satisfactory yield. In 1912 still better results as regards yield with other high quality Pusa wheats were obtained at Raipur and Tharsa, the results of the milling and baking tests of which will be dealt with in a later paper.

From the breeding point of view the fact that strength can be maintained, both under canal irrigation in the alluvium and also on the black cotton soils of the Peninsula, is of the greatest importance. It opens up a valuable direction of improvement which offers unlimited scope after the maximum possible yield has been realised. Canada at the present time has reached a high position in the Home markets on account of the high quality of the spring wheats produced in Manitoba. Indian wheats, on the other hand, although drier and often better grown, nevertheless fetch a lower price solely because of the relatively poor quality of the flour they yield. Once high quality is introduced into Indian wheats they will be at least as valuable as any produced in the world. They are already very dry and give a high percentage of flour and with quality added would at least be equal to the best Canadian grades.

The importance of the behaviour of a wheat in milling, apart from the quality of the resulting flour, is very great. Millers prefer wheats which absorb a large amount of water in the conditioning process without losing the character of free milling or, in other words, the capacity of allowing an easy separation of bran and flour. Many of the present soft white wheats exported do not absorb a great amount of water and do not mill well so that in improving the wheats of India the purely milling aspect must be considered. It will be seen in the tests that in addition to strength the high milling qualities of the Pusa wheats were also maintained when grown at other stations. In the improvement of the wheats of any tract the milling aspect of the subject should receive careful attention.

IV. YIELD AND QUALITY IN WHEAT.

In the literature relating to yield and quality in wheat there appears to be a considerable confusion of ideas. As this is likely to stand in the way of progress an attempt has been made in this chapter to define the position in so far as it applies to India. There is a general opinion that in some manner yield and quality are antagonistic and that high yielding wheats are always of poor quality. On the other hand, if quality is aimed at, then the yields are necessarily poor. At a recent discussion on the improvement of English wheat at the Farmers' Club in London these erroneous ideas were advocated by Percival[1] who maintained that, under English conditions, yield and quality cannot be combined.

The results of our experiments indicate that there is a definite connection between yield and quality. These experiments can best be understood and their significance realised if the two aspects of the whole question are separately considered. In the first place, the experimental evidence on the possibility of combining high yield and high quality in the same wheat must be considered. The second point relates to the conditions under which, in any particular wheat, the best quality can be obtained.

The first aspect relates to the combination of yield and quality in the same wheat. On this subject there is a considerable volume of Indian evidence. At Pusa, several new hybrid wheats with high grain qualities, raised from Muzaffarnagar, have for several years given higher yields than either parent. These are Pusa 100, 101, and 106 which were tested by Mr. Humphries in 1910 and found to behave like Manitoban good grade wheats produced in a dry season.[2] Several other wheats from the same cross, which have

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[1] *Journal of the Farmers' Club*, 1912, p. 80.

[2] Howard and Howard, *Bull.* 22, *Agricultural Research Institute, Pusa*, 1911, p. 14.

not yet received numbers, gave equally good results in 1912. In the trials of the strong wheats in 1911, Pusa 12 at most stations gave a higher yield than Muzaffarnagar, a result which is almost always the case when the two wheats are grown side by side at Pusa. In the case of gram (*Cicer arietinum*, L.) at Pusa, where many pure lines have been grown, the line with the highest quality is by far the highest yielder. Experience shows that there is no inherent antagonism between yield and quality and that both are possible in the same wheat.

Considerable attention has been paid at Pusa and afterwards at Cawnpore to the study of the conditions under which any particular wheat gives the best possible sample. As might have been expected the best samples were produced when the wheats gave the highest yield. The best samples were obtained after hot weather cultivation and clean fallowing during the monsoon when the objects aimed at were the absorption of water and its retention in the soil and subsoil combined with the destruction of all weeds. In this way yields of over 40 bushels to the acre have been obtained at Pusa without manure, without rain after sowing and without irrigation.

The higher the yield, the finer and more uniform the sample has been while the results of the milling and baking tests have always been most favourable in years of greatest yield. Thus in 1910 at Pusa, when the yields were the highest ever reached, the samples were particularly well spoken of by Mr. Humphries and gave very good results indeed when milled and baked. In 1911, the yields, due to very unfavourable weather, were lower, and in that year the samples were relatively poorer in appearance and the milling and baking results were also to a certain extent adversely affected. In the tests of Muzaffarnagar, grown at the various stations, a similar result has been obtained. The Cawnpore and Pusa samples have always done best in the milling and baking tests. At these centres this wheat has uniformly given higher yields than at the other stations. There is no doubt therefore that

in wheat growing the best sample is produced under those conditions which give the highest yield. This in reality clears up the whole matter as will be obvious from the experiments described below. These relate to hot weather cultivation and drainage—two important factors in wheat production in the alluvium.

A. Hot weather Cultivation.

In previous papers[1] attention has been drawn to the marked effect of hot-weather cultivation in the production of wheat and other crops, both *kharif* and *rabi*, in the alluvium of the Indo-Gangetic plain. During the early period of the wheat experiments at Pusa, when attention was being paid to the best methods of growing the crop under Indian conditions, it was decided to try the effect of opening up the stubbles immediately after harvest and so exposing the soil to the hot dry winds which prevail at this period of the year. The stubbles were ploughed several times and thoroughly opened up resulting in the production of a deep dry mulch of fine soil in which no growth of weeds was possible. This enabled all the early monsoon rains to be absorbed, and the subsequent procedure consisted in sufficient cultivation to keep down weeds and to break up the surface so as to allow of the percolation of more water into the subsoil. In this manner sufficient moisture was absorbed for a wheat crop of over forty bushels to the acre and the fields rapidly became free of weeds. In the lighter lands, the water holding capacity of the soil was increased by ploughing in crops of *san* (*Crotalaria juncea*, L.) raised on the early monsoon showers, but this has not yet been found necessary in the heavier lands.[2]

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1 See *Nature*, Feb. 17th, 1910; *Memoirs of the Dept. of Agr. of India* (*Botanical Series*), Vol. III, No. 4, 1910, and *Pusa Bulletin No.* 22, 1911.

2 If green manuring with *san* is attempted on heavy wheat lands in Bihar, in years when these soils are waterlogged after the green crop is ploughed in, the resulting wheat crop is always less than if no manure had been added. The addition of the green crop seems to accentuate anaerobic fermentation in the soil and to reduce the available nitrogen for the wheat crop. Fortunately such heavy soils retain water well and are not in need of green manure for this purpose. The fact that green manuring these heavy lands for wheat reduces the yield seems to indicate that on rice lands in Bihar green manuring with *san* would increase the yield considerably.

The effect of hot weather cultivation and moisture conservation was then tried at Cawnpore and, as at Pusa, the effect was instantaneous. The detailed results are published elsewhere, and it is sufficient to say that crops of between 25 and 30 mds. to the acre of high quality wheat have been produced using half the quantity of irrigation water employed by the cultivators in the neighbourhood.

At this point it became desirable to determine the actual crop increase resulting from hot weather cultivation. It was unfortunate that both at Pusa and at Cawnpore all the land had been thoroughly cultivated in the hot season for at least two years before the experiment was started and none of the area had been left in its original condition. Under these circumstances it was expected that no great differences would be detected the first year, and that it would take some time for the fertility to fall to the ordinary level of that exhibited by the cultivators' fields.

The experiment at Pusa was commenced after the harvest of 1910, and a level plot of typical wheat loam of high moisture retaining capacity was selected for the purpose. One half was cultivated during the hot weather, the remainder being left untouched till after the beginning of the monsoon. Across both plots a strip of land was manured just before sowing with nitrate of soda at the rate of 224 lbs. per acre and the results are shown in the following plan :—

Ploughed after the beginning of the monsoon.	Ploughed from the hot season onwards.	
32·02	37·89	Unmanured.
35·72	37·52	Manured with nitrate of soda at the rate of 224 lbs. per acre.
32·02	37·89	Unmanured.

The numbers in the table are bushels per acre.

The figures show that late ploughing caused a fall in the crop of six bushels of wheat to the acre, and that the dressing of nitrate of soda partially made up for the deficiency on the late ploughed plot but added nothing to the yield of the early ploughed plot.

The consistency, absolute weight and nitrogen content of the samples in this experiment are given in the following table. Those manured with nitrate of soda were darker in tint than the others, while those from the late ploughed plot were comparatively pale in colour and not so well grown as the rest.

Treatment of the land.	Consistency.			Weight of 1,000 grains in grammes.	Nitrogen percentage.	Yield per acre.	
	Hard.	Intermediate.	Soft.			Mds.	Bushels.
Ploughed early.	88	12	0	32·29	2·49	27·62	37·89
Do. + 2 cwt. of nitrate of soda per acre.	83	12	0	31·48	2·57	27·35	37·52
Ploughed late.	71	29	0	30·91	2·28	23·35	32·02
Do. + 2 cwt. of nitrate of soda per acre.	81	19	0	31·11	2·48	26·05	35·72

The standard maund consists of 40 seers and is equivalent to 82·271bs.

In the following year, 1911-12, the experiment was repeated on the same plot, but in this case no nitrate of soda was applied. There was a distinct difference in vegetative vigour between the plots and this is reflected in the yield of grain as will be seen in the results obtained.

1. Early ploughing—35·41 bushels to the acre.
2. Late ploughing—22·90 bushels to the acre.

The difference in yield during the past year was twelve and-a-half bushels per acre, or about twice that obtained the first year of the experiment. The results indicate that the effect of hot weather cultivation is cumulative and that the effects are not lost for some

time. The experiment is being continued until the yield of the late ploughed plot becomes steady, after which it is proposed to reverse the treatment of the two plots.

As regards quality, the appearance of the wheat from the late ploughed plot was distinctly inferior to the other. It was paler in colour and not so well grown as that from the early ploughed plot. In this case, while the plot with the higher yield gave the better quality, the fall in yield was greater than the difference in quality. This agrees with our experience at Pusa in wheat growing that in the case of the same wheat any adverse condition always affects yield much more than quality. When quality is sensibly lost it is almost certain that the yield is poor.[1]

B. Drainage.

During the progress of the wheat investigations in India one important factor in the growth of this crop has frequently been observed. This is waterlogging both previous to and during the growth of the crop. If wheat lands in Bihar are inundated for any length of time during the monsoon, or, if portions of the fields are continuously waterlogged for long periods, then a sour or semi-marshy condition of the soil results which is shown by a yellow crop of poor vegetative vigour and low yield. Often the consistency of the resulting sample on such areas is affected and a large proportion of mottled and soft grains are produced, which spoil the appearance of the sample and lower its market value. Similar results are to be seen in canal irrigated tracts in lowlying areas of the fields which get too much water and in which the soil becomes semi-waterlogged for long periods. These effects were distinctly

[1] In connection with these experiments the behaviour of the continuous wheat plot at Pusa may be of interest. This is a strip of typical wheat land which, for the past five years, has been cropped every year with wheat without manure. In 1911-12, the fifth year of the experiment, the yield per acre was 36·25 bushels, which is the highest yield of the variety (Pusa 22) so far obtained at Pusa. No diminution in vegetative vigour was observed. On the contrary, the growth was so great that a large portion of the crop was laid by wind soon after coming into ear which circumstance diminished the yield of grain. It will be interesting to see for how much longer these yields can be obtained and whether any organic matter besides the stubble need be added to the soil.

visible in the wheat plots at Bankipore and Dumraon in 1911 where wheat followed rice. The samples also contained a high percentage of soft and spotted grains. Drainage is therefore an important matter in wheat growing in India both as regards yield and quality even in areas where the crop is grown without any appreciable rainfall during the growth period. The long periods of rainless weather in India are apt to distract attention from the necessity of drainage. In reality, however, in a country where most of the rainfall is compressed into three months, the necessity of perfect drainage is even greater than in localities where the total precipitation is more evenly distributed through the year.

At Pusa, during the wheat growing season, 1909-10, which was preceded by a heavy monsoon, alternate strips of wheat and gram (*Cicer arietinum*, L.) were sown on a plot of heavy wheat land which was imperfectly drained during the monsoon. It was observed that while the gram was exceedingly good the wheat was poor and stunted with yellowish foliage and exceedingly small ears. The total crop was only a small fraction of that obtained on the rest of the field where the surface drainage was sufficient. The markedly different behaviour of a cereal and a legume growing under the same conditions in the presence of sufficient soil moisture suggested that the explanation of the difference would be found in the nitrogen supply in the soil. Accordingly the matter was made the subject of an experiment in the following year, 1910-11.

The monsoon of 1910, although well distributed, was small in amount and no waterlogging took place as the showers were absorbed and practically no water drained off the surface. In consequence, the land had to be artificially waterlogged and this was done during the month of September by pumping water from the river on to the area under experiment. The land selected for the experiment was well ploughed in the hot-weather of 1910 and fallowed till the end of August when the central portion was embanked and artificially kept wet during the whole of September. After drying sufficiently, the waterlogged portion was harrowed and ploughed up and managed in the ordinary way till sowing

time. Across the middle of the plots a strip was manured with nitrate of soda just before sowing, the total amount added being four cwt. to the acre. At first, the waterlogged area did best due to the abundant moisture but after tillering it rapidly fell behind the areas on either side. The nitrated strip in the waterlogged area soon became well marked but was hardly distinguished on the weathered plots on either side. The yields obtained are given in the following plan :—

The result of waterlogging wheat land at Pusa in 1910.

Normal cultivation.	Waterlogged during September.	Normal cultivation.
34·45	15·55	29·14
SHADED AREA TREATED WITH 4 CWT. NITRATE OF SODA PER ACRE. 35·92	25·17	26·53
34·45	15·55	29·14

The numbers in the plan are bushels per acre.

It will be seen that the effect of waterlogging for a month was to reduce the yield by about sixteen bushels to the acre while the nitrate of soda on this area increased the yield by nearly ten bushels. The effect of the manure on the non-waterlogged plots, as was expected, was very little. The results prove that the effect of waterlogging wheat lands in the previous monsoon is to interfere with the nitrogen supply of the crop and to lower the yield.

This result is of some general interest in Indian agriculture and particularly in those tracts of the plains like Bihar where rice and wheat are both grown. The lowlying areas in these tracts,

which receive drainage water from the higher lands, are generally planted in rice and these lands are often inundated and always waterlogged for long periods during the growth of the rice crop. The rice plant however thrives under these conditions and is able to take up its supply of nitrogen under waterlogged conditions, most likely in forms such as ammonia which are not suitable for other crops. In wet years like 1909 in Bihar the waterlogged and marshy conditions, associated with rice culture, may be said to have spread beyond and above the paddy fields and to have affected the wheat lands. This naturally influenced the soil processes and consequently the supply of available nitrogen for the wheat crop. Gram, however, being able to supply itself with nitrogenous food-material, was not affected and could thrive where a cereal like wheat to all intents and purposes starved.

From the economic standpoint the results of this experiment point to the great importance of drainage in the alluvial soils of India and the need of the limitation as it were of rice conditions to the areas which produce this crop. Where canals are used for watering the wheat crop it is also essential that the fields should be level so that all parts are equally watered. Where low areas exist, the surplus irrigation water drains into and waterlogs these areas and the result is a small crop of poor quality. On the black cotton soils of the Central Provinces it is often observed that the lowlying areas of the wheat fields often yield a larger proportion of spotted and soft grains than those parts which lie higher or are better drained. This partial waterlogging, which is more frequent in the black cotton soils than in the alluvium, is probably one of the chief causes of the unevenness in the consistency of the wheat often grown in Central India. The greater unevenness of the fields in Peninsular India probably follows from the fact that the levelling beam (*sohaga*) does not seem to be in general use in these regions. It is most important from the point of view of the miller that samples should be uniform in consistency otherwise a lower price is obtained for the wheat. The cultivator

in growing wheat of mixed consistency loses twice over. In the first place the yield is reduced and in the second place the quality is affected.

These experiments clearly indicate two of the main factors in the plains on which optimum yield and quality in wheat depend.[1] If cultivation is inadequate the yield falls and the quality is also affected. Want of drainage lowers the yield, affects the consistency and also lowers the quality. As regards wheat production it may be said that the best quality is obtained when the optimum yield is produced and that in any particular wheat, the ryot who produces the greatest yield has also secured the best quality possible in that wheat. If under these circumstances he grows a wheat in which high yielding power and high quality are combined he is then getting the greatest financial return for his labour.

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[1] Another important factor in wheat growing in the alluvium, in addition to hot-weather cultivation and drainage, may be mentioned. This is the treatment of the subsoil after it has been compacted by the monsoon rainfall. Experiments conducted at Pusa on the last three wheat crops, 1909-10 to 1911-12, have clearly indicated the advantage of a deep-ploughing towards the end of the monsoon. This aerates the subsoil, increases the root-range of the wheat plant and results in a considerable improvement in the standing-power of the crop as well as a better filled and more attractive sample. In the crop of 1911-12 the results of late deep-ploughing were particularly well marked. This cultivation must however be carried out without an undue loss of moisture—a matter of some difficulty in certain years with soil-inverting iron ploughs. On large estates it is possible that the best results will be obtained by the use of some form of sub-soil plough.

V. SUMMARY OF CONCLUSIONS.

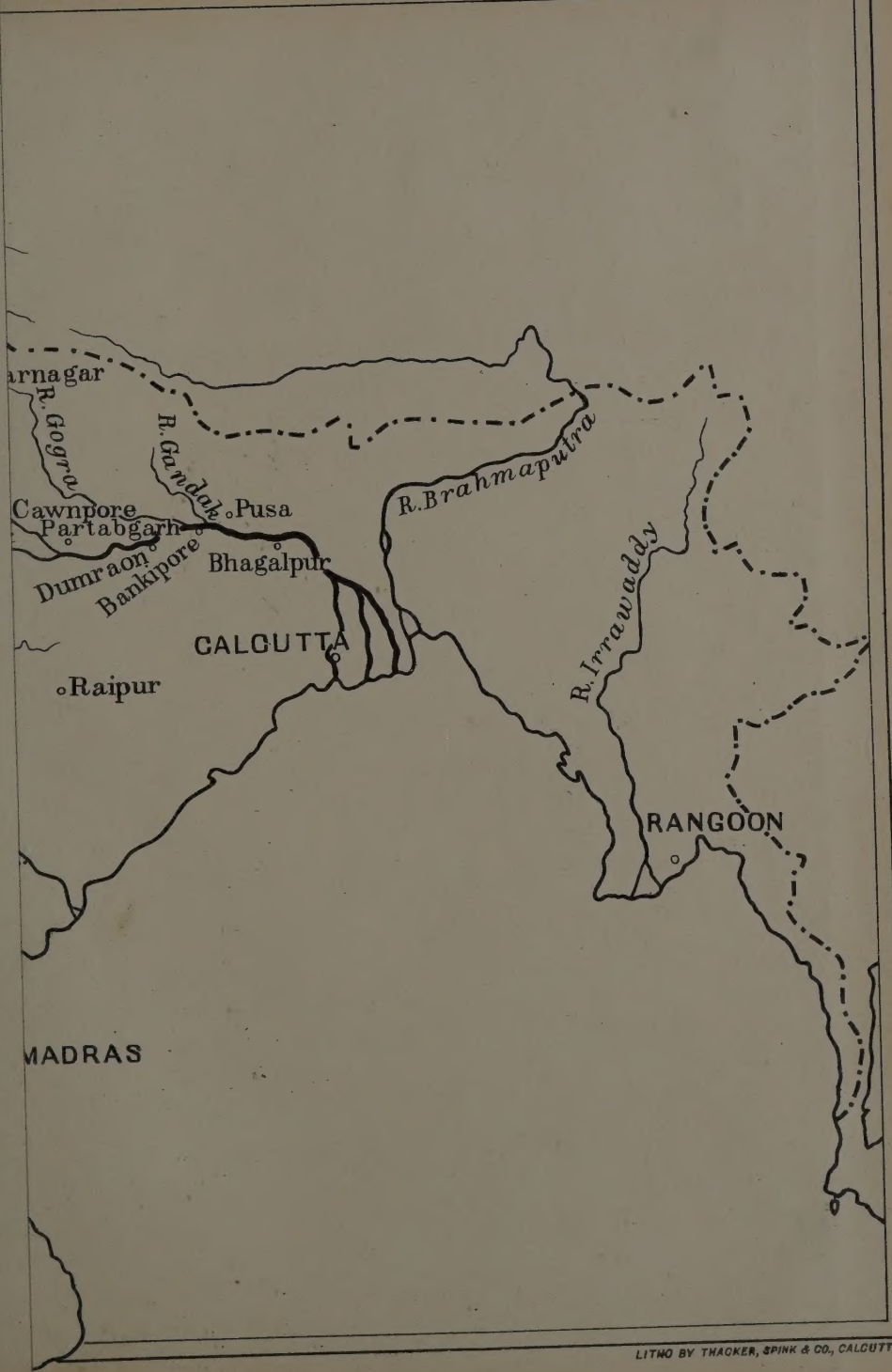
The conclusions arrived at as a result of the investigations described in this paper may be summed up as follows :—

1. Usually in India the consistency of a wheat varies greatly according to the conditions under which it is grown. Some translucent wheats however are affected to a much less extent than others while a few soft wheats have always remained soft.

2. Weak wheats like Muzaffarnagar can be improved to some extent in milling and baking qualities by cultivation, but they have not been made to behave like strong wheats.

3. Strong wheats with good milling qualities have been found to retain strength and milling qualities both under canal irrigation on the alluvium and also on the black soils of Peninsular India. In the future improvement of the wheats of these tracts the question of grain quality should receive particular attention.

4. Adverse factors, such as waterlogging and late cultivation, affect both the yield and quality of wheat in the plains of India. In any particular wheat, the conditions which produce the highest yield are those which also produce the best sample. In the same wheat high yield and high quality can be combined. To obtain the greatest financial return for his labour the cultivator should grow to perfection a wheat which combines high yielding power with high quality.



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